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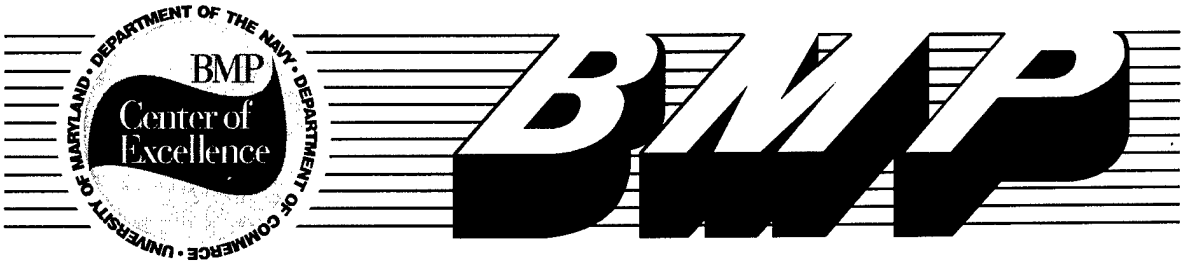

REPORT OF SURVEY CONDUCTED AT

LOCKHEED MARTIN
GOVERNMENT ELECTRONIC
SYSTEMS

MOORESTOWN, NJ

OCTOBER 1995

Best Manufacturing Practices

CENTER OF EXCELLENCE FOR BEST MANUFACTURING PRACTICES
College Park, Maryland

Foreword

This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective towards this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas highlighted in the Department of Defense's 4245-7.M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource to help companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to avoid costly and time-consuming duplication of what others have already tried and learned from.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Lockheed Martin Government Electronic Systems (LM-GES) conducted during the week of October 16, 1995. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from government, industry, and academia throughout the U.S. and Canada – *so the knowledge can be shared.* BMP also distributes this information through several interactive services including CD-ROMs, BMPnet, and a World Wide Web HomePage located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

LM-GES is located in in Moorestown, New Jersey, supports 3,000 employees, and was responsible for 1995 sales of approximately $600M. LM-GES is the AEGIS Combat System Engineering Agent responsible for the design, integration, and testing of a complete shipborne multi-warfare combat system. This encompasses all detection, command and control, weapon, and support systems for the guided missile cruisers such as the USS Ticonderoga and destroyers such as the USS Arleigh Burke. LM-GES also developed the Multiple Object Tracking Radar, a phased array antenna and high power transmitter combined with a powerful minicomputer; and the active, solid-state, multifunction battlefield Counter Battery Radar designed to detect, track, and locate enemy mortar, artillery, and rocket positions.

LM-GES achieved impressive goals over the last few years – those goals were reached because of an innovative Competitive Initiative with the local Union, and also due to LM-GES' Total Quality Management and continuous improvement efforts. These programs contributed to the reduction of touch labor by 26%, inventory by 80%, defects by 92%, and scrap by 81%. And those targets were accomplished in a *downsized* defense environment. Well-executed,resourceful procedures yielded a highly involved work force, and culminated with LM-GES being named one of America's Best Plants by *Industry Week* in 1994. It also won the 1995 New Jersey Quality Achievement Award which is based on Malcolm Baldrige National Quality Award criteria.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Lockheed Martin Government Electronic Systems expand BMP's contribution toward its goal of a stronger, more competitive, and more globally-minded American industrial program.

I encourage your participation and use of this unique resource.

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

Lockheed Martin Government Electronic Systems (LM-GES) is one of nine operating companies in the Lockheed Martin Corporation Electronics Sector. Located in Moorestown, New Jersey, LM-GES employs 3,000 personnel housed in 21 buildings covering 405 acres. In 1995, this Lockheed division produced approximately $600M in sales.

LM-GES is the AEGIS Combat System Engineering Agent responsible for the design, integration, and testing of a complete shipborne multi-warfare combat system. This encompasses all detection, command and control, weapon, and support systems for the AEGIS-class guided missile cruisers such as the USS Ticonderoga and AEGIS-class destroyers such as the USS Arleigh Burke. At the center of the Combat System is the computer-controlled AEGIS Weapon System, the core of which is the AN/SPY-1 phased array radar. The AN/SPY-1 can automatically and simultaneously track multiple targets while maintaining continuous surveillance of the sky from the sea to the stratosphere. Post production support includes Configuration Management, Life Cycle and Field Engineering, Logistics, Technical Training, and Depot Operations.

LM-GES developed the Multiple Object Tracking Radar (MOTR), a phased array antenna and high power transmitter combined with a powerful minicomputer, that can track 40 targets simultaneously. For the Army, the company also developed the active, solid-state Counter Battery Radar (COBRA), a multifunction battlefield radar design to detect, track, and locate enemy mortar, artillery, and rocket positions.

LM-GES encompasses many facilities in Moorestown including the AEGIS nearfield test and alignment facility, used to ensure the phased array radar's accuracy. There are also Production Test Centers which are used to integrate and test both cruiser and destroyer weapons systems, and the Combat System Engineering Development Site – or "Cruiser in the Cornfield" – which serves double duty as an engineering and test facility and U.S. Navy training site.

Future projects for LM-GES include the SC-21, Cooperative Engagement Capability, and CITADEL. In the SC-21 project, LM-GES is the lead on a joint Systems Command/Direct Reporting Program Management Project Office to initiate the Surface Combatant of the 21st century. Cooperative Engagement Capability will improve AEGIS Antiair Warfare capability by coordinating all four Antiair Warfare sensors into a single real-time fire control quality composite track picture. LM-GES built and tested the CITADEL prototype cabinet that will enable use of high performance, low-cost commercial computer processors, without modification, in a shipboard vibration and shock environment.

The changes in the defense environment in the mid-1980s affected all Government contractors, and LM-GES was no exception. In 1989, the company responded to changes by flattening its organization and abolishing thousands of positions. However, the IUE Local 106 union moved to team with LM-GES in an unprecedented partnership as both sides realized they had to work together to remain a viable business. This innovative Competitive Initiative demonstrated LM-GES' across-the-board support to maintain a level workforce. LM-GES listened to new ideas, facilitated implementation, and opened lines of communication. Aggressive goals were set – and *met* – such as reducing touch labor by 26%, inventory by 80%, defects by 92%, and scrap by 81%, to name just a few. By implementing the Competitive Initiative, what was scheduled to become additional outsourced work on components for the AEGIS system translated into the retention of 400 labor positions planned for elimination at LM-GES. These efforts culminated with LM-GES being named one of America's Best Plants by *Industry Week* in 1994. It also won the 1995 New Jersey Quality achievement award which is based on Malcolm Baldrige National Quality Award criteria. Although the company benchmarked best-in-class companies in management-labor relationships before making significant changes, the Competitive Initiative *became* a benchmark in exceptional joint efforts.

LM-GES' Total Quality Management and continuous improvement efforts are complementary and critical to the company's competitive survival. While TQM represents an overarching philosophy, continuous improvement provides the yardstick for measuring progress. Consequently, LM-GES has aggressively pursued their integration into the company culture. These pivotal efforts are based on a strong top-down TQM program and a formalized, four-phase Continuous Process Improvement Roadmap. With TQM initiatives beginning in 1991, productivity has been enhanced 64%, the component yield has risen, and on-time delivery has reached 100% with zero customer rejects. Based on seven years of continuous improvement efforts, teams at LM-GES reduced critical manufacturing process cost drivers while improving process efficiency through

operator involvement, operator improvements, and operator ownership. These well-executed, innovative procedures have yielded a highly involved work force committed to continuous improvement and Total Quality Management.

Lockheed Martin Government Electronic Systems has a long history of quality dating to the early 1960s when it was part of the RCA Corporation, later when it was a member of the General Electric Aerospace team, and subsequently as a division of Martin Marietta. That tradition of quality has been a critical component of the successful history of the U.S. Navy AEGIS program. With its strong workforce and aggressive TQM/Continuous Process Improvement initiatives, LM-GES will continue to produce practices such as the following examples the BMP survey team found to be among the best in government and industry.

Best Practices

The BMP survey team documented the following best practices at LM-GES.

Information

The following information items were identified at LM-GES.

Activity Point of Contact

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Section 2

Best Practices

Design/Test

Advanced Signal Processor Hierarchical Wirewrap System

LM-GES engineers have been developing a software tool to automate the design, fabrication, test, and maintenance of the company's Advanced Signal Processor Backplanes since 1991. The original hardware designs for the backplanes were created by interconnecting all backplane connectors with wirewrap connections. Although the manufacturing process of these assemblies employed Gardner Denver and other automated wirewrap machines, the process was still expensive and labor intensive due to the special wiring constraints. Design, redesign, fabrication, and test were slow and subject to error.

The Wirewrap Integrated System Design Optimizing Maintenance (WISDOM) System developed to address these problems used the Mentor Graphics Engineering Workstation and software initially developed by Design Automation to automatically extract netlists, perform wiring designs, and generate NC data that automated the manufacturing, test, and maintenance processes. LM-GES engineers have continued to improve the system until all of the design and manufacturing processes now leverage data from the package. The hierarchical or bussed logic diagraming methodology used by the system has reduced engineering logic development time, but the most throughput gains have been achieved by moving all post-processing tools onto the high speed Engineering Workstation. This has enabled local interactive creation of all outputs, many of which had previously required batch processing or even remote data center processing.

The menu-driven system is simple to operate and uses the Mentor front-end processing to design the backplane wiring. New backplane designs incorporate a mix of printed wiring circuit paths and wirewrap connections. The designer enters the circuit into the CAD system as if the entire design was going to be a PWB. Each interconnection is then labeled by the designer as to whether it is printed wire or a wrapped wire. The system sorts the data and creates all necessary files to manufacture the PWB portion of the design, test it, assemble the components, wrap the rest of the wiring, and test it again.

WISDOM has grown into a general purpose wirewrap CAD tool and will continue to evolve. It has many other tools, enhancements, and features, and has become a powerful tool because of a supportive environment for its maturation.

Automated Test Stations

LM-GES uses three AEGIS Automated Test Stations – RF, digital, and analog – for testing various subassemblies. Each test station integrates varied RF, digital, and analog measurements into a single connection for testing ease. The stations allow RF measurements such as gain, phase, differential phase, and spectrum analysis to be taken on solid state transmit/receive modules and RF devices in high volume quantities. The Automated Test Stations are computer-driven using a UNIX operating system, and contain guided probes capable of repeatable measurements needed for high-volume, tight-tolerance requirements. Using these automated test stations, LM-GES can conduct high speed testing of dynamic and numerous specifications while collecting data at one station. The stations also provide accessibility of data for analysis on individual lot diagnostics for research and development, or provide a production platform for easy conversion to other programs or devices. These test stations provide high volume throughput.

- **RF/Microwave** — The Automated RF Test Station provides automated measurement and alignment of microwave subassemblies with high-volume throughput and high accuracy requirements. Some alignments are accomplished by laser or robotic dent tuning. Resistor trimming is computer-driven with direct interface to a closed loop laser trimming station. The computer determines optimum values and controls actual trimming of resistors in a circuit. It also determines capacitive tuning requirements from RF electrical length measurements. The computer downloads the requirements to a controller in real time through a computer interface. The process results in a highly accurate, repeatable, high-volume throughput, with database accessibility for analysis and trends. It also enhances system test and field depot measurement capabilities by providing equipment mobility.
- **Digital Test** — The Automated Digital Module Test Station is a surface mount workcenter that uses the Teradyne L297 and L321 for simulation and functional testing of high density ASIC and Programmable Logic Device Technology modules. The Digital Module Functional Test is capable of testing both surface mount and through-hole technologies from the edge connector with vector application. The Teradyne L297 is used for higher speed and edge resolution greater than five nanoseconds, while the L321 is for edge resolution of five nanoseconds or less. Both systems can measure

time/frequency and voltage. The test station performs populated substrate testing on a bed of nails; performs edge connector functional tests with specific input stimulus; is capable of diagnostics through nodal verification and a guided probe developing a nodal library; and allows off-line programming capabilities using additional workstations performing programming/test multifunctional operations. The simulation results give a quantitative grading of the effectiveness of the test to detect faults. Generation Guidelines are used for building a test vector and simulation module design strategy.

Currently, the Teradyne L297 is Joint Test Action Group (JTAG) Boundary Scan, IEEE 1149.1 capable when it is designed into the module. Incorporation of JTAG Boundary Scan Testability enhances testing and increases fault coverage without sacrificing board real estate. Good board simulation verifies the board functionality to the designer's ideas. Fault simulation will grade vectors of board simulation for possible undetected faults. This facilitates resimulation to upgrade board simulation to detect those previously undiscovered faults.

The Engineering Process Improvement Design is used to establish Testability Best Practices. The advent of more complex designs using ASIC and Programmable Logic Devices elements and smaller packages on modules renders present methods such as in-circuit or guided probe impractical to impossible. Also, the Engineering Process Improvement Design provides a tool for implementing a test vector strategy, accomplished on the Mentor V8 platform using a test vector method compatible with Quicksim II simulator. Also, the hierarchical design and simulation provide the ability to independently test and simulate each block in the design. JTAG is an emerging design-for-testability technique in design and testing of modules which simplifies field diagnostics while lowering manufacturing costs and enhancing system quality. The benefits to this program include that JTAG will verify the functional operation of the module-under-test and will provide a high level of fault detection/fault isolation.

- **Analog Test** — The Automated Analog Module Test Station measures module performance using test positions to meet engineering specifications. These positions are populated with state-of-the-art General Purpose Interface Base programmable test equipment such as the latest Hewlett-Packard Spectrum Analyzers, Network Analyzers, and Low Phase Noise Synthesized Signal Generators. LM-GES engineering test positions meet the exacting measurement requirements for testing Signal Processor assemblies of the Navy's AEGIS system and have the ability to test at a range from low frequency applications through X-band. Universal test fixturing provides a variety of digital and analog control signals configurable to most any unit under test. The turnkey test platform is controlled using PCs running customized programs and software written in Microsoft Visual Basic, TransEra HTBasic, and HP Basic. All multiband RF measurements are made using a single test position instead of multiple stations formerly required to measure gain, phase, loss, and noise figure. Software is also developed to completely automate all RF testing. Limiting manual intervention minimizes setup time. The fixtures and interface panels are designed for multiple types of RF analog module testing. Test programs are user friendly, providing a fast, efficient way to test complicated analog modules and subassemblies easily. Also, these automated analog module test positions greatly reduce test time and amplify the operator's ability to troubleshoot test units. LM-GES can adapt these positions to most configurations and perform small or large production runs.

Computer Program Change Management

In 1990, the Computer Program Development and Systems Engineering organizations at LM-GES began using a computer tool, management controls, and two review boards to control and track changes to computer program products throughout their life cycles. The Specification Change, Review, Implementation Baseline and Evaluation Board (SCRIBE) was established to prevent unauthorized and ill-developed changes from being made to programs and specifications between the Critical Design Review and delivery of systems to the customer. The process required more oversight and discipline; a tool was needed to report on the status of changes. The Status Tracking and Reporting System (STARSYS) was available to all AEGIS team members and provided the necessary mechanism. Two boards now review and decide the fate of proposed changes; the management controls ensure that changes work inside the system; and the computer tool provides on-line visibility of information needed by all decision-makers involved in the changes.

The Software Implementation Board directs the creation of computer program change requests and determines their baseline applicability and operational priority according to DoD-STD-1679A. The SCRIBE takes over after the Critical Design Review. Each board helps streamline the process, resulting in customer approval of well thought-out changes as needed. Application of approved changes usually occurs from two weeks to one month from the board decision.

STARSYS is an integrated tracking and reporting system for computer programs and documents. It is the primary source of configuration management and metrics for

process and product measurements. STARSYS provides users who need information with real time status of all AEGIS computer programs and baselines which includes 26 years of documentation of system engineering recommendations, analyses, and closures of Computer Program Change Requests and Specification Changes on a state-of-the-art client server network.

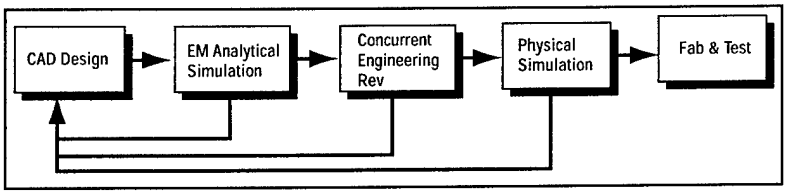

Figure 2-1. Simplified Electromagnetic Performance Simulation Process Flow

There has been increased discipline provided by the formalized processes. The use of STARSYS helps ensure that decisions of the board are well founded, and it now requires less process time to review, evaluate, decide, and implement proposed computer program source code changes. STARSYS provides accurate status on all computer program changes recommended for a baseline element. Additional benefits also include immediate feedback and timely approval by the customer. Customer approvals now come more quickly, and the system enables the board to weigh and consider cost, resource, and schedule impacts before reaching a decision.

Electromagnetic Performance Simulation

Design and optimization of complex microwave devices/systems previously required extensive physical experimentation to expedite evaluation and selection of design approaches at LM-GES. Highly skilled personnel in electromagnetic theory were needed to derive complete analytical solutions, and scientific programmers skilled in numerical methods to code and debug analytical solutions. These processes were time consuming and expensive to perform since a failed design required substantial work to reformulate solutions and reprogram new design approaches.

However, by using commercial and proprietary computer-based analytical simulation tools to design and optimize complex microwave devices/systems, LM-GES has reduced the development time by at least 50%. A physical simulator built to validate computer simulation and verify final design and manufacturing processes is used to authenticate the computer simulation, provide feedback for tuning of the analytical model, and verify fabrication and assembly processes (Figure 2-1).

Using simulation, cycle time has been reduced by 50%, manpower reduced from two work-years to six work-months, system performance improved through computer statistical optimization techniques, and required skills shifted from highly specialized theorists and programmers to broad-based microwave engineers.

Electronic CAD/CAM Interfaces

LM-GES has been developing a suite of interfaces to allow it to leverage production tools directly from its CAD databases. The goal is to automatically generate the manufacturing data from controlled design databases and electronically distribute the data to LM-GES workcenters and suppliers in a paperless environment.

LM-GES has already replaced the paper and magnetic tape control of its NC machines with local networking and has linked many other processes by computer postprocessing (Figure 2-2). Besides internal use of the data, LM-GES has

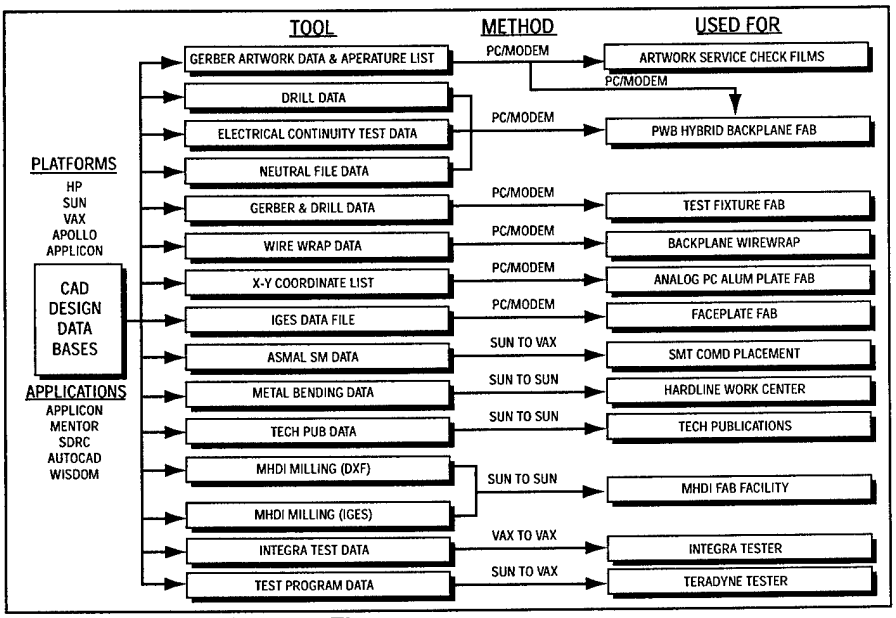

Figure 2-2. New Process Flow

attempted to understand its suppliers' processes to supply them compatible data formats. This detail has extended the benefits of data leveraging outside the LM-GES sphere. Misinterpretation of requirements is minimized; suppliers do not have to expend time and resources to translate the data into the parochial formats; and products can be supplied cheaper, faster, and with reduced risk.

Every new data link has resulted in an increase in productivity. LM-GES has realized an estimated 400% gain in productivity since this development began in the late 1980s. The gain is directly translatable into improved quality, faster response, and reduced manufacturing costs.

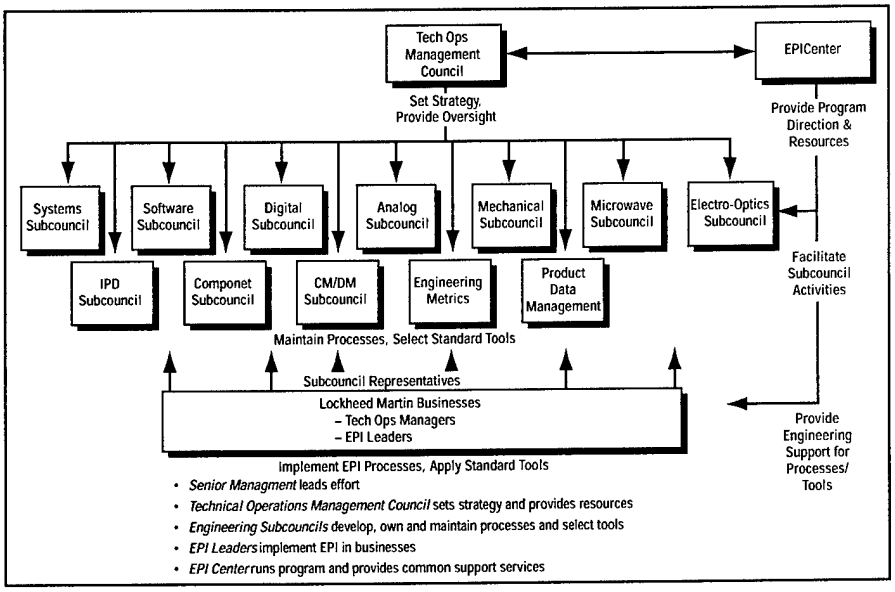

Figure 2-3. EPI Infrastructure and Resources

Lockheed Martin Engineering Process Improvement Approach

Since 1990, LM-GES has increased productivity by 5% per year by standardizing design tools and structuring teams from all fields through its Engineering Process Improvement (EPI) program. Cost savings in areas of procurement, training, and maintenance have also been realized through this program. The EPI Approach was based on a year-long Booz-Allen-Hamilton study in 1988 of GE Aerospace and 11 other aerospace and commercial businesses. The study identified best practices, and the EPI Approach then focused on more than 100 of these practices in 10 areas. GE Aerospace remapped design processes at all sites while embedding the best practices.

Over the first three years of the program (1990-1992), overall productivity in the participating businesses improved 28% when adjusted for changes in sales. Analysis of this data by the Engineering Managers indicated that approximately 5.5% resulted from implementing EPI best practices and CAE tools (Table 2-1).

The EPI subcouncils, owners of the engineering processes, were established (Figure 2-3) to evaluate suppliers of CAE tools to determine which tool best fit individual subcouncil requirements. With management support – an integral part of the process – the EPI subcouncils were able to map key engineering processes, identify best practices, standardize engineering processes, train engineering personnel in processes and tools, provide central standardization services, and measure productivity for continuous improvement.

Table 2-1. Examples of Improvements Due to EPI

Discipline	Engineering Task	Reduction in Effort
Systems Engineering	Documentation of Subsystem Definition	25%
	System Specific Generation	50%
Software Engineering	Ada Software Development	30%
	Acoustic Processing	45%
	Generate Database for Visual Simulation of Terrain	44%
Digital Engineering	ASIC Design	44%
	Printed Wire Board Design	50%
	Circuit Test Vector Generation	25%
Analog Engineering	Printed Wire Board Design and Drafting	65%
	Surface Mount Board Design	50%
	Battery Power Conditioner Design	30%
	Circuit Simulation	99%
RF/Microwave Engineering	Amplifier Breadboard	100%
	Transmit/Receive Module Input/Output Design	90%
	Communication Subsystem Design	20%
Mechanical Engineering	Rapid Prototyping of Mechanical Parts	85%
	Spacecraft Configuration Structural Design	38%
	Chassis Structural Analysis	85%
	Mechanical Design of Visionic Data System Structure	47%
	Antenna Structure Analysis	75%

EPI Processes and Tools have Reduced Engineering Cost and Cycle Time in the Major Engineering Disciplines

By simplifying early involvement of all concerned disciplines, it was possible to standardize CAE tools and reduce compatibility problems between the disciplines. Costs were also lowered by exercising large-quantity buys of standard equipment. Transferring EPI CAE Software Licenses provided significant savings. LM-GES greatly reduced training and support costs by using fewer different tools and from sharing lessons learned across all sites.

The EPI subcouncils provide cross-functional support of Integrated Product Development, Components/Preferred Suppliers, Configuration/Data Management, Engineering Metrics and Product Data Management as an ongoing task. Other tasks include Application Engineering support, CAE Software Procurement/Supplier Interfaces, Component Models/Libraries, Standards Updates, EPI Documentation Control, EPI Leader/Subcouncil Leader Integration, Communications (EPIGram, Site Visits and Lessons Learned Database), and Integration with the governing body, Technical Operations Management Council.

Materials Management and Accounting System

The Materials Management and Accounting System at LM-GES has undergone extensive changes. In 1990, the system acted as an oversight function and was concentrated around meeting Federal Acquisition Regulations. The customer (Navy) would review and approve company-generated processes, and meetings with LM-GES would often occur after issues or findings had taken place. Functional elements of the manufacturing process acted independently, resulting in inconsistent materials measurements, and results not did always coincide with business and customer needs.

As a result of Government findings in 1991, LM-GES changed and upgraded its Materials Management and Accounting System. The system is designed with functional processes that are effective, efficient, and compliant across different business elements. Material measurements are integrated across the entire manufacturing process and represent tools to manage results. Processes are developed by the owners, and cross-functional ownership of the complete materials process is designed into the system. A dedicated team was established to manage the system from contract receipt to delivery and provide a single point ownership of the system. The team is designated the Business Systems Integration team, and supplies focused direction and analysis for material system changes and improvements.

Customer and business goals are now achieved through concurrent development, execution, and management. Employees support the process as part of their normal daily activities, and business commitment toward continuous process improvements and successes are supported by known benchmarks. The system provides effective and efficient compliance to business and customer requirements.

Using the Material Management and Accounting System at LM-GES has produced dramatic results (Table 2-2), and is applied to the entire business utilizing a program management philosophy of cross-functional responsibilities. The system provides for an open book approach to allow oversight organizations and customers to participate in the development and management of the business practices and improvement of these processes.

Table 2-2. Before and After Materials Management and Accounting System Upgrade

	BEFORE	AFTER
Bill of Material Accuracy	30%	98%
Material Disbursement Accuracy	65%	99%
Excess/Obsolete Materials	25%	5%
Scrap Level	>10%	~1%
Spare Delivery Performance	65%	99.9%

Naval Systems Computer Center Network Management Process

In support of its extensive Naval Systems Computer Center (NSCC), LM-GES established a network management process that includes a centralized network management workstation. The complex, geographically dispersed NSCC is a pivotal component of the successful AEGIS program. Operating non-stop, the NSCC provides a heterogeneous environment; supports legacy of Standard Navy Computers and Advanced Processor Technology Insertion; and supports a large number of users at multiple sites with intensive network traffic for simulations and graphics. By developing a network management process based on the centralized network workstation, LM-GES has seen substantial reductions in down time.

In the NSCC Network Management Process, network agents are installed on critical network devices. Probes are used to enhance the metric collection capability and facilitate real-time trend analysis and problem prevention. The network link integrity is monitored by continuous probing (pings), and network performance is supervised by polling data elements managed by the system. Trapping mechanisms trigger operator alerts, and network/system administrators are electronically contacted and dispatched to address any problems. Management reports for planning and optimization, allocation of computer resources, and detailed analysis are provided by utilizing the control database.

The metrics collected by the system indicate network performance. Capacity planning, reliability, availability,

performance tuning, problem prevention, problem resolution, trend analysis, and root cause analysis are supported by the NSCC management process system. Open problems have been reduced by 57% since November 1994 using the system, and it supports the growth of the NSCC network. It also accommodates new technology insertion and supports AEGIS advanced processor requirements development. Non-technical support staff can monitor the network and identify problems, and redundant network equipment is eliminated since problems are corrected real-time.

An example of the network management process illustrated a 1200% improvement in network downtime. The example also showed that engineering productivity lost time was decreased to zero, and the time required for a network administrator to solve a problem was reduced by 338%. Future improvements to the system include aggressively inserting high-speed technology into the NSCC network, implementing automatic fail-safe capabilities, and continuing to improve the network performance to customer facilities.

Producibility Experts and Design Review

LM-GES uses Producibility Experts and other technical experts to conduct design reviews and provide the best technical solution against requirements, producibility, standardization, and life cycle cost criteria. The design review process consists of Concept, Implementation and Pre-release reviews. To improve the first-pass success rate, the Design Review Team includes experts from Engineering, Operations, Sourcing, Quality, and Program Management, as well as the Producibility Experts.

The Producibility Expert Program was initiated in 1990 to address problems related to attrition. To maintain and advance the technical expert base in commodities, LM-GES established a recognized system of experts to convey both lessons learned and current processes to the design community to improve the total cost performance of new designs. The Producibility Expert's role is that of consultant and design reviewer inserted into the design process prior to Design Review. This practice has lowered the Drawing Change Rate, as seen in a three-year strategic benchmarking study (Figure 2-4).

Benefits of this program include the ability to contact experts on call for design engineering; process information and lessons learned are inserted early into the design process; and manufacturing releases are clearer and more producible.

Semi-Rigid Coaxial Cables

The AEGIS SPY-1B/D Phased Array antenna requires 4,350 coaxial cables to connect the phase shifters to power dividers, and 2,172 long flexible cables to connect the power dividers to the combiner board. LM-GES determined that changing flexible coaxial cables to semi-rigid coaxial cables could result in significant cost savings.

The first challenge to overcome was to successfully route the semi-rigid cables through the assembly. Flexible cables could be easily bent and made to fit within the assembly, while the semi-rigid cables had to be formed and placed correctly prior to being connected to the phase shifters or power dividers. Initially, the path was planned through manual iterations – or trial and error. The Advanced Signal Processor Program was a pilot program to develop software that would generate solid model routings for the semi-rigid cables. This software resulted in designs that followed rules and guidelines for cable shapes, minimum and maximum lengths, and bend radii developed by LM-GES Manufacturing Engineering. Once the route was planned, the software could translate three-dimensional coordinate data through a conversion program to a bend data file which could be downloaded to a cable bender.

Semi-rigid cables were first used to connect the phase shifters to the power dividers. There were 17 families of cables (based on length and shape), from 8-30 inches. All families had an established physical length to meet the phase length requirements. The modeling software was used to plan the routing of the cables, and the data was transferred to automated cable benders which formed the necessary cables. Connectors were manually placed on the cable, manually attached to the power dividers and phase shifters, and sealed with shrink sleeve. To minimize phase length deviations, the cable was procured in 1,000-foot lots that had to contain cable from the same Teflon core lot.

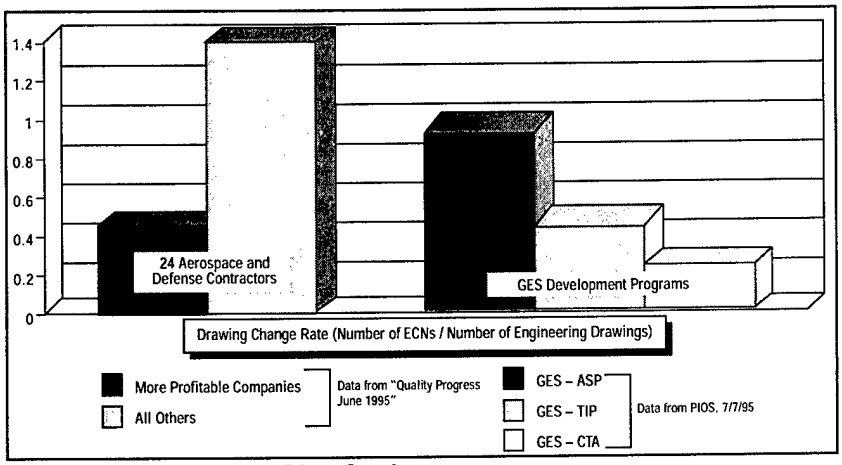

Figure 2-4. Benchmarking Study

Additionally, all cable had to meet LM-GES specifications which exceeded military specification requirements.

The next phase of implementation was to use the semi-rigid cables to replace the 2,172 flexible cables connecting the power dividers to the combiner board. The cables were much longer and the routing more complex because these cables were in a confined space. Besides satisfying physical length and phase length requirements, the routing had to minimize crossing other lines and avoid interference with other antenna column components. These cables could be divided into 17 different cable lengths ranging from 35.5 inches to 109 inches. These were purchased cut and finished direct from the manufacturer, where they were tested and labeled with the exact length. Additional software was developed to enable the operator to enter the precise cable length to be formed, and the software with the automated bending tool would form the cable. These were then manually placed and attached. The cables, unlike flexible cables, required some foam padding to minimize vibration.

Since implementing this process, there have been no drawing changes initiated by Manufacturing, since the cables were routed prior to placement. LM-GES developed a more straightforward assembly process, and reduced scrap 50%. Test results have shown a 99.997% yield in the design and manufacture of the semi-rigid cables.

Software Quality Assurance Program

The Software Quality Assurance (SQA) organization at LM-GES focuses on preventing defects through process improvement rather than detecting and counting errors resulting from the process (Figure 2-5). Current contracts still require product evaluations, and defect removal is still tracked, but SQA personnel emphasize their role as process improvement facilitators instead of inspectors, auditors, or reviewers. SQA chairs the AEGIS Standards Improvement Group, leads software process standardization efforts, and trains Software Engineers on the Computer Program Standards. It has also implemented numerous improvement recommendations to the Computer Program Standards. One improvement is the development of a common coding standard which specifies a common commenting template across all computer languages used on the AEGIS program.

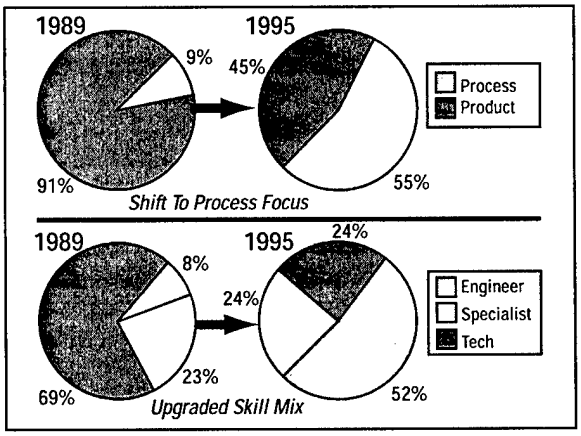

Figure 2-5. Software QA Shift to Process Improvement

These changes were initiated in 1989 with a change in military requirements. The LM-GES SQA program is almost twice as cost effective as other programs, as indicated by the Software Productivity Consortium Metrics Guide. The GES SQA effort constitutes 3.76% of applicable engineering manpower as opposed to the Software Productivity Consortium published range of 7% to 15%. Furthermore, the LM-GES process focus allows SQA to support multiple projects and baseline developments. To continuously improve the SQA function, feedback from internal and external customers is obtained through a quarterly Customer report card which provides ratings on performance, responsiveness, and communications.

System Level Integration and Test

System level integration and test of production AEGIS weapon systems at LM-GES' Production Test Center (PTC) prior to shipboard installation and test comprise a major factor in the overall success of the AEGIS program. System level integration and test of each unique complex weapon system greatly reduce the cost and schedule risk for the shipyard activities.

The system level integration and test consist of seven stages.

1. Stage 1 is material receipt and inspection at the PTC.
2. Stage 2 is installation and checkout.
3. Stage 3 is initial light-off of individual elements.
4. Stage 4 is intra-element checkout (Radar System Element, Weapon Control Element, etc.).
5. Stage 5 is interelement testing (Radar Element with Weapons Control System Element, with Fire Control System Element, with Command and Decision System Element).
6. Stage 6 is production reliability and AEGIS acceptance test.
7. Stage 7 is de-installation, final inspection, pack and ship.

A multifunctional coordination team organizes all activities at the PTC. This team consists of the leaders of each PTC functional activity who have met daily since 1994 to review schedule status and coordinate objectives for the day. These morning meetings have minimized activities that might otherwise conflict with each other while fostering team spirit. This practice has resulted in a 25% reduction in defect rate and a 17% reduction in cycle time.

In conjunction with the coordination team meeting, the PTC self-audit program enhances Stages 2 through 7. This frequent audit program involves all workcenter employees. Each assigned person, at defined intervals, participates as part of a PTC audit walk-through team. This assigned audit responsibility heightens the awareness of each participant concerning division policies, functional instructions, standards, Government regulations, and contractual requirements with which all must comply. This self-audit practice has resulted in an average 68% reduction in FY95 findings when compared to FY94.

System level integration and test is required by contract to demonstrate satisfactory operation of each AEGIS weapon system prior to delivery. The system level integration and test accomplished in seven coordinated stages is a well-controlled process that feeds information back to the Design, Development, and Manufacturing groups. Approximately 200 free-standing cabinets are received from five main suppliers and connected via approximately 1,000 cables. The process reduces shipyard installation problems, minimizes testing at the shipyard, and validates shipyard test procedures. It results in timely, coordinated delivery of 680 line items (23 truckloads) of an operational AEGIS weapon system with the latest production capability to the Fleet.

Production/Facilities

AEGIS Depot Operations

The AEGIS Depot Operation (ADO) is collocated in Moorestown with Lockheed Martin's Naval Systems and AEGIS Production organizations. ADO's principal functions include staging Navy Furnished Material for production integration, repairing Lockheed Martin manufactured material, coordinating repair of interim supported material and core AEGIS INCO spares, and staging AEGIS Field Modifications/Ordnance Alteration (ORDALT) kits. The Naval Systems has performed as both Combat System Engineering Agent and Integration Agent since inception of the AEGIS program. Collocating these organizations has resulted in significant cost savings to the Government.

Collocating the ADO and the AEGIS production organization has enabled ADO's repair personnel to receive current, comprehensive training from the production organization; provided the capability to supplement both equipment and personnel to the ADO during peak repair loads; and provided access to proper expertise to quickly resolve design and production-related repair problems.

There is a significant cost saving to the Navy that results from the Depot's Test Methods Engineers and Testers/Repair Staff being "graduates" of the LM-GES AEGIS Production on-the-job experience. The Depot contract does not pay for the schools that these senior people have attended and does not pay for the on-the-job time that has made them senior staff prior to their association with the Depot. Additionally, AEGIS' experienced, temporary peak load staff is made available to the AEGIS Depot by Production when required. A standalone Depot would not have parttime senior personnel available.

Chemical Laboratory/Failure Analysis

LM-GES strongly supports its on-site chemical/failure analysis laboratory, and has integrated it into the manufacturing process so virtually no product is produced without being affected in some way by the laboratory. Originally established as a Product Assurance Laboratory in 1967, the chemical/failure analysis laboratory maintained a primary responsibility of testing incoming materials and controlling chemical processes for PWB manufacturing. The chemical/failure analysis laboratory has greatly expanded responsibilities of failure analysis; addressing environmental health and safety concerns; supporting design, process, and producibility improvements; supporting suppliers; and providing product life support by performing tests such as water sampling.

The benefits of fully utilizing and expanding this in-house laboratory include:

- Scrap, rework and repair are reduced by careful monitoring of processes.
- Drifting parameters can be identified and corrections made readily.
- Compliance of suspected lots of incoming material is determined prior to use (and before, due to work with suppliers).
- Cycle times are improved by the instant feedback provided by a captive laboratory.
- Accuracy of results is improved because of the analyst's familiarity with the processes used in house.
- Company-sensitive or proprietary information stays in the plant.

Confined Space Entry Program

Employee safety is a critical aspect of business at LM-GES, as demonstrated by the company's comprehensive confined space entry program. The program ensures safe entrance into what are normally unoccupied spaces. The OSHA defines a confined space as one that is large enough and configured such that an employee may enter only to perform assigned work, has limited means of entry or exit, and is not designated for continuous employee occupancy.

A thorough confined space entry program is critical because this area accounts for the most accidental, work-related deaths in industry.

LM-GES manufactures high-mix, low-volume products that require a diverse manufacturing site for assembly. The confined space entry program identifies all those confined spaces, assesses hazards potential, documents entry procedures requiring training and certification of entry personnel, contains procedures for summoning emergency response personnel, and requires periodic reviews for continued assessment of procedures and entry options.

LM-GES has identified 61 confined spaces within the manufacturing area, all of which require an entry permit for access, and 77 employees have been trained and certified in the confined space entry program. This successful effort serves as a model to other organizations such as the Moorestown Township, and LM-GES provides supportive training and guidance. The program was implemented in 1992, and there have been no accidents or injuries at LM-GES resulting from confined space entries.

Contractor Safety Program

In mid-1993, LM-GES experienced a harmless chemical spill which highlighted the lack of control the company had on contractors working in the plant. To correct the problem, Lockheed Martin GES developed a proactive program to define and control all work by contractors.

Four areas were identified for implementation of this program. First, contractor work procedures were needed. Second, any unique risks involving outside contractors had to be identified. Third, the contractor had to understand and comply with site policies. Finally, any costs associated with regulatory laws had to be identified.

LM-GES requests work procedure information from prospective contractors during the invitation-for-bid process. This information details the work equipment to be used, special training/certification requirements and any hazardous materials used or generated. Upon arrival, all contractor personnel must view the safety video and understand plant requirements before issuance of a contract admittance card. Contract compliance is proactive by work site inspections, violation notices, and disciplinary notices.

LM-GES' Contractor Safety Program reduces the risk for the company, its employees and contractors. Contractors who adhere to the program requirements gain credibility in the local contract community because of the LM-GES comprehensive Contractor Safety Program.

Defect and Scrap Reduction

Scrap generation and defect production are important conditions when evaluating a company's performance, and LM-GES established a program 1991 to both measure and reduce these parameters. Prior to this time, the organization had no formalized plan for reduction. For scrap, there was a limited breakdown of collected data, and the data was not in a format that allowed meaningful analysis, only reflecting the highest dollar items. Review of the data was led by Engineering Management in a closed meeting. Little of that information was relayed to floor personnel where the greatest impact could be produced, leaving open a significant opportunity for improvement.

LM-GES has since established multifunctional teams in each workcenter; each team brainstorms a list of metrics for the workcenter that are monitored, including defects and scrap. Performance is then measured against these metrics weekly and is rated green, red, or yellow. An important aspect of this effort includes the linking of the company suggestion program to team efforts and performance.

Benefits have been demonstrated throughout the company. Defect performance has improved from 157.1 defects per million in 1993, to 139.8 defects per million in 1994, to 96.5 defects per million through October 1995. Scrap generation has dropped by a factor of five to one since 1990. In addition, this approach has yielded intangible benefits such as improved problem solving and corrective action skills, an increased sense of ownership by the teams, lower costs, higher quality, and a more educated workforce.

Fix or Delete Supplier Program

LM-GES developed the Fix or Delete Supplier program in 1993 to evaluate key suppliers on quality, pricing, and other factors such as on-time deliveries. A matrix for assessing critical suppliers includes the categories of Focus on Quality, Fix or Delete, Focus on Price, and Grow Supplier. The Fix or Delete process helps create plans for specific corrective action for suppliers. In 1992, only one supplier out of 20 was rated as a Grow Supplier, a supplier that LM-GES would continue to grow with.

The Fix or Delete process has been a valuable tool for both the company and the suppliers. It identifies the resources required and the level of commitment of the supplier, and identifies performing suppliers for future growth. It is also an excellent internal and external communication tool.

In 1995, 16 out of 20 critical suppliers are rated as Grow Suppliers. Seven of these suppliers have received AEGIS

Table 2-3. Results of Fix or Delete Process

	1992	9/95	%
PO Cycle Time • Growth in GPA's	45 days	13 days	71%
Supplier Reduction • Fix or Delete matrix	3,650	580	84%
On-Time Delivery Performance • Supplier Report Cards	44%	78%	77%
CSP Suppliers • Supplier Symposiums	12 (93)	148	1233%
PMI CycleTime • CSP Program	40 days	5 days	88%
Problem Sheet Cycle Time • Metric generation/ownership	43 days	13 days	70%
MR Backlog • GPA's, Supplier Reduction	7975	1530	81%
MR's>60 days • System Upgrades	3400	63	98%
Discrepant Invoices	1003	28	97%

Excellence Awards for their commitment to the project, providing multiple improvements (Table 2-3).

Group Purchase Agreement Process

In 1990, LM-GES implemented Group Purchase Agreements (GPAs) across 19 sites for competitive pricing. Common suppliers previously established different pricing for different facilities, and the different pricing was normally attributed to the different quantities being offered. The GPA process centralized the purchasing through systems, policies, and practices.

An Advanced Sourcing Organization manages the process while site sourcing organizations drive the process in subcontracts. The Advanced Sourcing Organization has established GPAs for 18 commodity areas including resistors, capacitors, machining, castings, and PWBs. Over 119,000 different parts are covered in 1,117 purchase agreements. By using GPA, one contract is released for different organizations with different delivery dates requested. This has resulted in significant savings since pricing for larger quantities can be achieved and has also reduced the supplier base from 3650 in 1992 to 580 in 1995. Cost reductions from using these agreements are also realized throughout the procurement process since there is less paperwork and a reduced cycle time.

Life Cycle Parts Control Process

The LM-GES ADO has devised a system (Figure 2-6) to screen all incoming parts to ensure their compliance with source control drawings. ADO receives about one-third of its parts through the Navy Supply System MILSTRIP process where parts are purchased from specification control drawings which emphasize technical requirements rather than supplier qualifications. If a suggested supplier no longer produces a part, MILSTRIP may buy it from another supplier.

LM-GES AEGIS parts are purchased almost exclusively from source control drawings, and for some parts it is not practical to specify all critical parameters. For these parts, LM-GES relies on specific parts suppliers to provide parts that will function properly. There is a high likelihood that parts controlled by source control drawings that are obtained from other than qualified suppliers will not operate properly or will fail prematurely.

If unqualified parts are used for repair, at least 25% of 100 parts would cause premature failure of the Line Replaceable Units (LRUs) in which they are installed. The cost of repairing these failed LRUs is estimated to be $150K annually or $6K/part. Additionally, 4% of SPY-1A, and 1% of SPY-1B/D radar LRUs are mission critical. It is estimated that at least one SPY-1A critical failure per year, and/or one SPY-1 B/D critical failure every fourth year would be caused by one year's use of unqualified parts.

Under the new LM-GES ADO screening system, if a part is not compliant with source control drawings, a 10-day

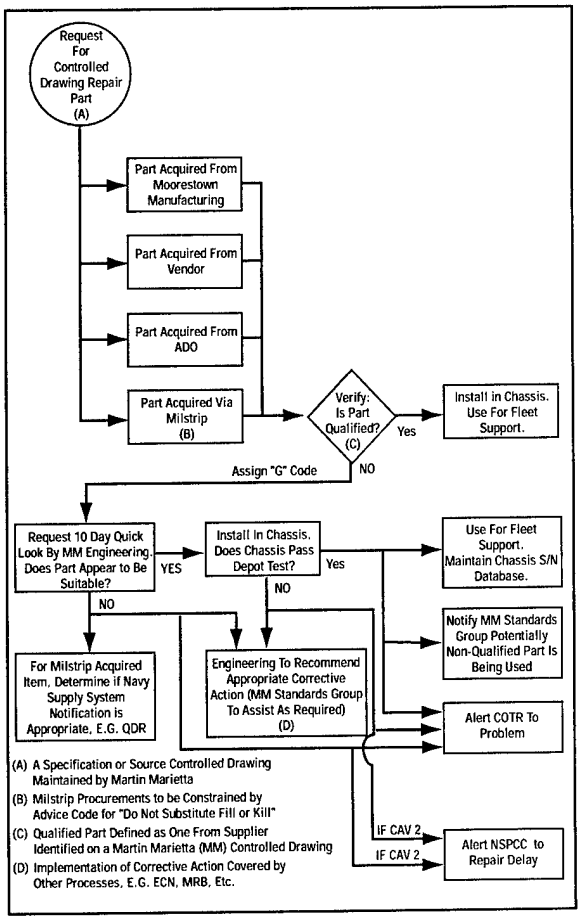

Figure 2-6. LM-GES Parts Screening System

Engineering quick-look analysis is performed and interim approval provided for parts judged low risk. The location history of assemblies repaired with interim approved parts is maintained and the normal parts qualification process is then initiated.

Plated Through-Hole Rework Process

In the late 1980s, GES together with the Navy technical community consisting of the Defense Plant Representative Office (DPRO), Naval Weapons Assessment Center, AEGIS Technical Representative, and the McLaughlin Research Corporation, explored the possibility of salvaging defective PWAs. Multilayer PWAs had always been scrapped when damaged or defective plated through-holes were detected. This action created unnecessary production schedule delays and high production costs.

In late 1991, GES implemented a plated through-hole rework technique for PWAs using a through-hole plating rework system manufactured by GEC Marconi and utilizing GES' in-house plating chemistry and manufacturing process. This technology essentially replaces the barrel of the hole and the pad utilizing the same chemical processes that were used during the original board fabrication. The through-hole plating rework system isolates the plating process to the one hole requiring rework. The reworked PWAs meet applicable MIL-P-55110 criteria and are identical in all respects to the original.

The plated through-hole rework process has resulted in significant success for GES and the Navy. Since implementation, 293 assemblies totaling 615 reworked plated through-holes have been completed. The process has produced a 100% reliability factor for PWAs in the field.

Robotic Phase Shifter Assembly

LM-GES uses automation when assembling the phase shifter component in the AEGIS SPY-1B/D housing because of the difficult touch labor involved, as well as the relatively high volume of assemblies produced (18,000 units per shipset). Manual assembly was difficult and labor intensive, as the fragile garnet interior component could easily be scratched or chipped, resulting in the scrapping of the assembly. The phase shifter requires repeatable assembly to tight specifications to ensure microwave performance characteristics.

The automation involves three workcells consisting of Seiko D-TRAN robots which use programmable logic to simultaneously perform multiple, complex tasks. The first workcell is used to pick and place 0.045-inch eyelets and ground contact springs to the SPY-1B/D housing. The assembly then goes to the second workcell, where four rivets are placed onto the housing. The workcell then spreads the tubular housing just below its elastic limit and inserts the fragile garnet assembly into the housing to within $\pm$0.002-inch in all directions. The housing is then closed while holding the garnet assembly. The third workcell automatically feeds a sub-miniature, A-sized coaxial connector, bends the microwave sensitive probe precisely five degrees, and attaches the connector to the assembly using a patented Room Temperature Vulcanizing Silicon Encapsulate wetting method. The connector is placed over four rivets, and finally riveted into place to ensure no microwave leakage.

The automation of the phase shifter assembly has had many advantages. Two shift operations are now performed during a single shift with one operator for each of these operations. The automation is reliable enough to free these operators to perform quality checks and chart SPC data while the automated assembly operation is performed. This has resulted in an over 60% reduction in touch labor. Also, the manual process variations and damage due to manual assembly are significantly reduced.

Some of the lessons learned can be applied to automation in general. First, backup procedures must be maintained, and regular preventive maintenance must be planned and performed. Also, management and operators must both work closely together throughout the planning and implementation to make this level of automation work.

Sourcing Systems

In 1990, LM-GES had 17 different purchasing agencies, each using its own unique system. This has been combined into corporate-wide strategic systems that maximize corporate leverage, enhance on-line data, and reduce administrative material costs. The new systems in place are Consolidated Purchasing System, the Supplier Quality System, and the Material Estimating and Tracking System.

LM-GES realized that many different purchasing systems were inefficient and not cost effective. By centralizing the procurement system, starting with common strategic systems, purchasing has become more efficient and cost effective. From a corporate perspective, data is now available on part history, price history, and total volume, allowing LM-GES to make informed decisions on purchase order awards.

By establishing one consolidated purchasing system, tremendous leverage with suppliers was obtained through visible corporate requirements. Common Supplier measurements were obtained with a Supplier Quality System. A supplier rating system was developed using supplier report cards to get feedback. A Material Estimating and Tracking System provided timely decisions in data, strategy, and decision marking and purchase order awards. The purchase order cycle time has been reduced by 71% (to 13 days) since

1992. The on-time delivery performance has improved by 78% (to 79%) since 1992.

Supplier Certification Program

LM-GES maintains a comprehensive certified supplier program that provides benefits to both LM-GES and its suppliers. The company is committed to – and demands commitment from – its suppliers and the Certified Supplier Program reflects that two-way commitment.

Suppliers can achieve three different levels of certification. Bronze level requires a 100% quality part rating, a minimum of six lots delivered, an approved quality system, and is applicable to an individual part number or families. The Silver level mandates, in addition to Bronze requirements, an SPC program, an on-site review, a business assessment, and a management letter of intent. Gold level includes Silver-level requirements as well as a Total Quality/Continuous Process Improvement program.

Certified suppliers receive benefits such as reduced surveillance, preferred procurement status, and increased visibility across the Lockheed Martin Corporation. LM-GES benefits include quality products, lower cost to ensure those quality products, continuous cost control, and a premier supplier base. The Purchased Material Inspection yield has improved by 2.1% (to 99.2%), lot backlog has been reduced by 67% (to 400), and cycle time has been reduced by 55% (to 5 days). The reduced returned material from the floor has been reduced by 66% and scrap was reduced by 87%.

Logistics/Management

Acquisition Reform Integrated Process Team

LM-GES realized that acquisition reform measures that make defense systems more affordable and take advantage of commercial practices and technologies also make sense from a business standpoint. In response to the high-level interest from the Department of Defense and the Navy, an Integrated Process Team (IPT) was formed with LM-GES to develop and implement acquisition reform measures on the AEGIS weapon system production program. AEGIS is a long-standing, successful program with mature product design and processes. The IPT approach presented the optimum means to ensure that risks associated with the introduction of commercial specifications or commercial-off-the-shelf equipment would not adversely impact performance, reliability, or life cycle support.

The IPT is comprised of Government representatives from the Navy Program Manager's office, Navy support and field activities, DPRO, Defense Contracting Auditing Agency, and industry representatives from the three prime weapon system contractors of LM-GES, LM Defense Systems, and Raytheon. Subcontractors also have input and involvement on an as-required basis. The team is chartered to pursue improvements to the acquisition process that eliminate non-value-added requirements and facilitate the utilization of commercial practices and technologies while managing the risk of acquisition reform in an ongoing production program.

The IPT approach offers an opportunity to capitalize on the synergy of the three prime original equipment manufacturers and to maximize the effectiveness and timeliness of activity through the teaming of government and industry. Candidate projects are identified and sub-teams are assigned by the IPT to drive them to conclusion. The sub-teams are tasked with evaluating their assigned projects for relevance and impact and making recommendations for appropriate action to be taken. Recommendations from the sub-teams are reviewed by the full IPT and form the basis for coordinated reform action across the program.

As of late 1995, nine candidate projects had been assigned to sub-teams for impact assessment. Three candidates resulted in specific changes to current contracts and/or current practices. Actions taken as a result of these projects include elimination of subcontractor ESS and the component and module levels; modification of existing paint and surface finished specifications to allow use of environmentally-improved alternatives; and streamlining of the non-standard part approval process.

In the case of three other candidates, IPT sub-team assessment revealed that the program had previously taken action and that potential savings had been previously been realized. The remaining three candidates are still under review. The IPT approach results in efficiency of effort and produces buy-in from both government and industry. Implementation of improvements is consistent across the program because of involvement of all stakeholders.

Behavioral-Based Safety Performance

LM-GES instituted a Behavioral-Based Safety Performance program in 1994 directed at the individual employee instead of centering on "command and control" themes that resulted in diminishing returns. The Behavioral-Based Safety Performance program was also designed to support the OSHA trend of developing standards which required employee involvement in hazard identification and elimination. LM-GES also determined that employees who are more aware can prevent hazards from developing, thereby reducing the possibilities of injury.

LM-GES has implemented the program by training employees through videos, written material, and administering knowledge tests. An innovative "Safety Coupon

Table 2-4. Injury and Illness Rate Trends

YEAR	DAYS AWAY FROM WORK CASE RATE[1]	RECORDABLE RATE[2]	LOST WORK DAY RATE[3]	RESTRICTED DAY RATE[4]
1992	2.57	5.52	78.31	33.24
1993	2.31	4.98	54.16	35.21
1994	1.68	4.89	39.95	19.68
YTD 1994	1.83	5.49	16.89	17.50
YTD 1995	0.95	2.82	16.64	14.31
BLS RATES FOR SAME SIC CODE AND # OF EMPLOYEES[5]	1.9	4.6	N/A	N/A

1 – Days Away From Work Rate includes injuries and illnesses resulting in days away from work and days of restricted activity.
2 – Recordable Rate includes the total number of all OSHA-recordable injuries and illness
3 – Lost Work Day Rate includes all days away from work due to work-related injuries and illnesses
4 – Restricted Day Rate includes all days of restricted work activity due to work-related injuries and illnesses
5 – BLS is the Bureau of Labor Statistics which publishes "Evaluating Your Firm's Injury And Illness Record." These standards are taken from the 1991 edition.

System" encourages employees to identify and correct hazards. In this program, employees complete safety coupons with a health or safety finding and a corrective action that was taken to eliminate the hazard. The coupons are then deposited in a box for a monthly prize drawing. A Safety Committee has been assigned to each workcenter to track items from finding to closure, thereby providing a closed-loop system. Every work discipline, including the union, is represented on the Safety Committee.

Through this Behavioral-Based Safety Performance program, LM-GES employees are more aware of health and safety issues. Positive feedback has been provided, and employees are recognized for their contributions. In just one year, OSHA recordable rates were reduced by 48%, and there was an 80% decrease in lost workdays (Table 2-4) This was accomplished with a safety staff of only five personnel, the smallest staff proportion of all Lockheed Martin facilities.

Characteristic Verification Program

As TQM and other team-oriented programs progress, operators and other floor personnel at LM-GES are given more responsibility for their work and the work of their team. The company has developed a Characteristic Verification Program (CVP) to provide floor personnel with the necessary tools to identify and correct defects in a controlled manner.

CVP is a process (Figure 2-7) with which operators perform in-process checks to verify their own work. When an operator identifies a defect in the assembly he is working on, he records the defect and compares it to the control limit. If the limit is not exceeded, the operator then reworks the defect and continues. If the limit is exceeded, the operator stops the process and corrective action is initiated by the team. Vital elements of the program include a formal qualification plan (essentially a sampling plan that the customer agrees to), the use of real-time SPC, and an emphasis on defect prevention.

The program is being implemented in teams. Understanding of the most advanced team concepts and implementation can require up to 12 months overall. All production work teams are advancing towards the CVP process. The process begins with on-the-job training for the team, identification of critical operations, selection of operator trainers, and overall CVP process review. A critical cross-training matrix is also developed at this time where qualified operators are identified for each of the critical operations and key areas for cross-training opportunities are identified.

Operators are qualified, followed by SPC training when control charts are developed with the operators. The Quality Assurance Plan is then produced, and other support training such as listening/communications, and non-conforming material is provided to the team and the process is tested in a trial run. The entire effort is then presented to the customer for approval.

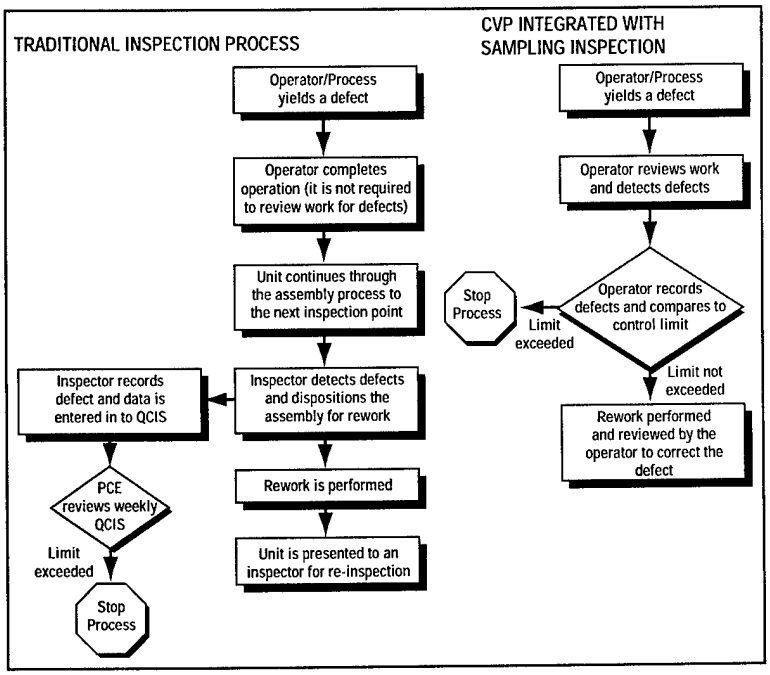

Figure 2-7. Characteristic Verification Process Flowchart

Since implementing CVP in selected workcenters, LM-GES has realized an overall reduction in the time associated with the rework process. The operator is able to identify defects and perform any necessary rework before it is inspected. The operator is also able to recognize defect trends in real time and stop the process if required. Since defect reports were previously issued on a weekly basis, as much as a week's worth of production would have to be inspected if a trend was detected to determine when the defects started. Comparing 1992 cost of defects for one workcenter to 1994 cost of defects, a total savings of $34,682 is realized. The cost of labor attached to scrap material for the same workcenter and time period has been reduced over $16K.

Configuration Management Plan

LM-GES uses two essential and effective tools in its Configuration Management (CM) program. The CM Plan describes how LM-GES CM policies are applied to major weapon and combat systems in development, production, and system test at both local and remote sites, and during systems integration. The CM Manual then provides more detailed information on all aspects of the CM Plan. Together, these tools have provided LM-GES with a comprehensive configuration management program.

The LM-GES CM Plan describes how configuration management policies are applied to major systems, and specifically describes the configuration management organization, responsibilities of the Configuration Projects organization, and the functional relationships between Configuration Projects and other remote sites. The Plan also describes how configuration management disciplines of configuration identification, change control, status accounting, and auditing are applied uniformly to program contracts for systems, equipments, and software. Finally, the CM Plan defines relationships between LM-GES and appropriate acquisition agents, design activities, and other Government activities.

LM-GES developed and implemented its CM Manual which very effectively expands the CM Plan to include detailed standard procedures/directives/instructions, specific job tasks, allocation of requirements, orientation and directories, and a repository of lessons learned that captures years of experience resident at LM-GES. Another unique feature provided by the configuration management program shows the correlation between the CM Plan disciplines and ISO 9001/10007 requirements.

Refined periodically to reflect the programmatic circumstances and requirements changes, the CM Manual and Plan are LM-GES' critical components in a very successful Configuration Management program.

Customer Satisfaction Index

One aspect of the LM-GES TQM approach is customer focus, and the company has therefore developed a Customer Satisfaction Index (CSI) to receive objective feedback from external customers. The CSI rating is visible to all levels of the organization. The DPRO provides monthly information based on standard criteria for each workcenter. These ratings are discussed with personnel in the workcenter before being displayed.

The CSI includes the following characteristics:

- Workcenter responsiveness to DPRO Quality Assurance Representative concerns
- Appropriate/effective use of process data
- Repeat issues/inadequate corrective action/failure to implement corrective action
- Support process compliance/breakdowns directly related to workcenter
- Workcenter organization/housekeeping
- "Release Quality" (inspection escapes).

Each characteristic is graded green, yellow, or red. Green is for isolated issues or no issues. Yellow is for repetitive isolated issues or an isolated major issue. Red is for loss of confidence or inability of LM-GES to control a process.

The program was expanded to include major customers at the two AEGIS shipyards. Shipyard personnel provide a quarterly CSI with characteristics that include communication, documentation, corrective action, equipment receipt, equipment installation, and equipment test support. For shipyards, rating criteria is slightly different, where green is for isolated issues or no issues. Yellow is for repetitive issues or impacts to shipyard load-out/test schedule. Red is for safety hazard or severe impact to shipyard schedule and overall performance.

LM-GES has found the CSI to provide an objective assessment of workcenters and processes. It is a means of providing communication from DPRO and shipyard sites to LM-GES, and fosters the LM-GES continuous improvement philosophy.

Defect Library

A joint LM-GES/DPRO/Naval Warfare Assessment Division project in 1988 created work aids which visually portray workmanship criteria. In the late 1980s, LM-GES recognized inconsistency in the interpretation of specifications and drawings. Documentation was not readily available and what was available was not easily understood. Inadequate word pictures and drawings hindered the training of operators and inspectors. Production inefficiencies existed from misinterpretation of specifications. There was

a need for an effective way to maintain production standards over time and through changes in personnel.

LM-GES has assembled an extensive library of scrapped hardware, pictorials, and photos demonstrating examples of preferred, maximum-acceptable, and rejectable conditions. All examples are maintained under QAE configuration control with DPRO approval of additions or changes. The aids create consistency in training of operators and inspectors. Misinterpretations of specifications and drawings are eliminated, resulting in a reduction of unnecessary cosmetic rework. The defect library was originally implemented on printed wiring boards and has expanded to other work centers including the Production Test Center.

LM-GES' defect library has successfully promoted product quality and consistency. Aids are used to maintain and communicate criteria defined in contracts. Consistent training is given to operators and inspectors, and production delays due to Material Review Board (MRB) actions and costly rework are eliminated. Standards are maintained over time and personnel changes.

Engineering Change Proposals

LM-GES has developed an effective process to expedite and control the generation, review, and approval of all in-house AEGIS Engineering Change Proposals (ECPs). The ECP process applied in the AEGIS program has several elements common to other ECP cycles (Figure 2-8). However, LM-GES has realized significant time savings by focusing on the level of review and by utilizing a computerized review and approval system.

During the draft stage of the ECP, experts from the Program Office, Reliability and Maintainability, System Engineering, Logistics, Cabling, Test Engineering, Government Furnished Equipment, Ordnance Alterations, System Specifications, ORTS, Sites, and Life Cycle review the proposal and provide technical expertise input. This level is followed by a formal meeting of representatives from 26 (depending on the specific proposal) called the Change Review Group, who approve the change as it impacts individual areas of responsibility.

The final level of the review and approval comes from the Configuration Control Board who reviews the ECP at the management level of the 13 organizations in LM-GES. It provides an opportunity to adjudicate any unresolved issues from the Change Review Group. This forum provides the final approval for submittal to the Navy.

These three levels of participation in the ECP process minimize errors and greatly impact the quality of the document. The process also reduces the quantity of comments and/or corrections that typically result from Government agency reviews. Another intangible benefit is that this process facilitates a more thorough in-house understanding of the overall system baselines and other proposed changes.

A significant element in this ECP process is the use of a computerized system called the Work Flow Manager for LM-GES review and approvals. The basis of the Work Flow Manager is a commercially available tool, the Process Management Engine (PME™). Reviewers are provided a virtual copy of the original ECP to see changes as they are made by the originating engineer(s). It is more accurate and provides for a more timely review cycle.

Before implementing various process improvements in 1992 and the Work Flow Manager in early 1994, ECP cycle times averaged 115 days. Since 1992, ECP cycles have averaged only 52 days, realizing an over 50% reduction in cycle time. The AEGIS program office has recognized the value added

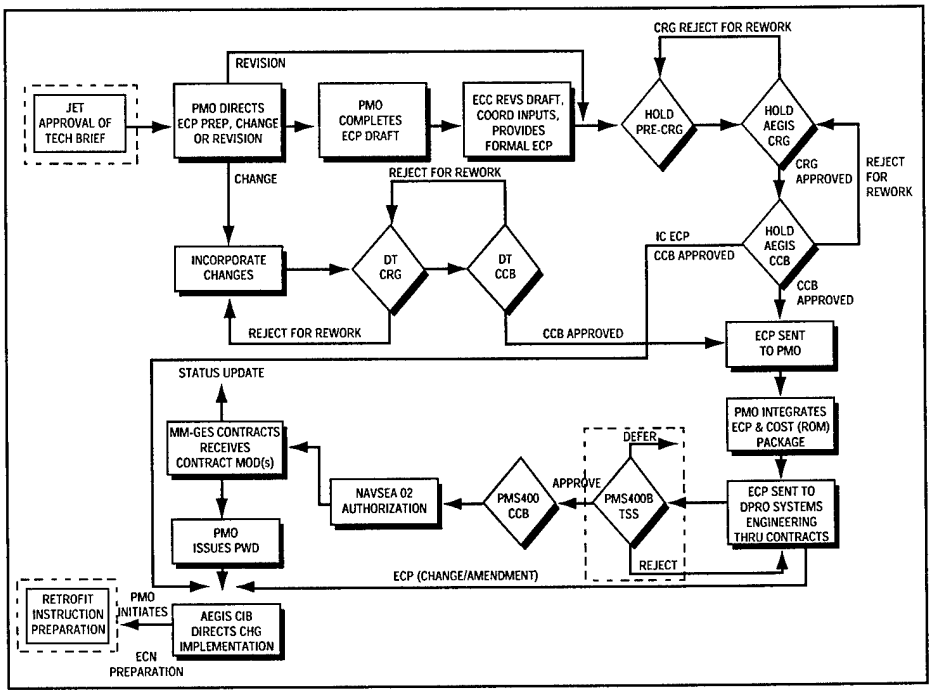

Figure 2-8. ECP Process

of this LM-GES process and has proposed assistance in streamlining external configuration management processes.

Failure Review Board Process

The Failure Review Board (FRB) process at LM-GES is actually a preventive failure review process in which each aspect of the process is focused on methods and techniques to prevent failures before they become a statistic. The FRB process monitors activities and trends of future designs, current production, and field operation of all LM-GES equipment and systems to ensure timely problem identification and corrective action.

LM-GES established the FRB to oversee the failure review process to reduce or eliminate problems that go undetected or receive no corrective action early in the system life-cycle. The Navy customer, system integrators, and equipment design contractors comprise the FRB which conducts surveillance of field operations, system level testing and integration, manufacturing, and new design and development efforts. Independent but cooperative review meetings are held at the equipment and system levels. The process includes problem and deficiencies identification, tracking for unfavorable trends and high cost drivers, in-depth analysis and investigations, corrective actions, process improvements, ECPs, provisioning optimization, and cost reduction initiatives.

LM-GES developed a unique tool to identify any potential problems. The experienced/prediction ratio for each component indicates whether a component is performing within the requirements predicted by the designer. A ratio less than one indicates the component is performing within its expected design parameters; greater than one indicates that the component is performing outside its predicted design parameters. These and other trend analysis tools are used by the FRB to effectively conduct failure (or preventive failure) review.

System cost and/or cost avoidance, reliability, and schedules have been positively impacted by the effective operation of the FRB through a variety of corrective actions and redesigns. Through the FRB actions, the operational cost per ship/year for repair or replacement of failed items has been reduced by 60% between 1983 and 1994. In addition, the cost of on-board spares required to support operational availability goals has been reduced by 35%.

Japanese AEGIS Material Staging

The establishment of a Japanese AEGIS Material Staging Activity presented several unique challenges to LM-GES. It met this Foreign Military Sales (FMS) challenge by establishing a comprehensive organizational infrastructure (Figure 2-9). This activity developed detailed FMS staging procedures and guidelines, trained staff members to accommodate unique requirements, and established an extensive mainframe database/reporting mechanism to facilitate program control.

The FMS challenges included the uniqueness of size, the AEGIS system integration on Japanese ships, and the interface with foreign weapon systems. Other unique program requirements included material identification/status and tracking services to the piece part level; development of material packaging lists and cargo transfer document forms in accordance with FMS requirements; consolidation of materials from multiple sources; and technical assistance to Japanese freight forwarder representatives in the proper handling/transport of AEGIS equipment.

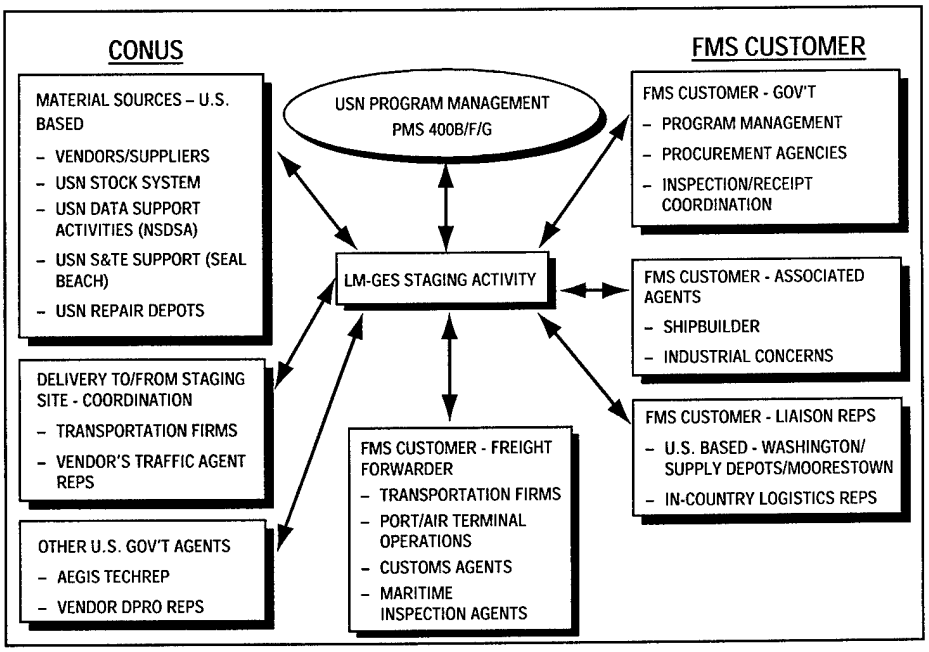

Figure 2-9. Staging Interface Network

To successfully implement the Japanese AEGIS Material Staging Program, an integrated network of interfaces has

been established with particular focus on Data Management/Control. In support of this goal, LM-GES has established a mainframe database at Moorestown that has unique computer programming developed to directly interface with primary program participants. This database, known as the Japanese Status and Tracking System, serves as the centralized logistics management tool used to track the due-in, receipt, staging and shipping status of all materials procured for Japanese AEGIS FMS cases. It enables an automated flow of data to facilitate material control activities. This effort has enabled on-line access to staging data by multiple users; provided efficient material control features eliminating redundant data; allowed staging documentation (packing lists/label data) generation; furnished flexible reporting capabilities tailored to meet unique customer requirements; and facilitated data acquisition/transfer features between users (Figure 2-10).

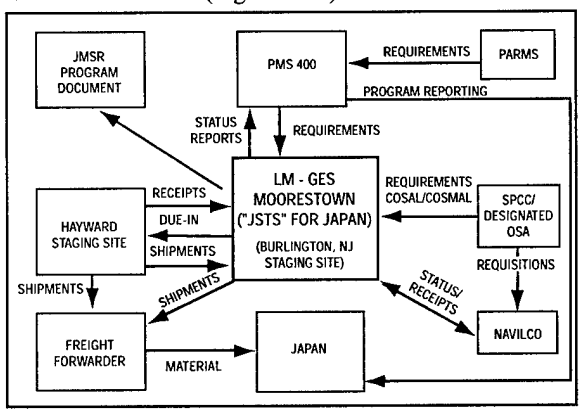

Figure 2-10. Foreign Military Sales for Japanese Staging Program - Data Flow Network

The result of the effort is an LM-GES Japanese AEGIS Material Staging Activity responsible for full management and delivery coordination for all FMS supplied material and documentation. The Japanese AEGIS Material Staging Activity has processed 1,200 shipments since 1989. These shipments included three ship-sets of end item equipment (2,500 crates); 2,200 crates of support materials, spares and test equipment; and 300 crates of technical documentation. The activity not only successfully delivered all AEGIS system equipment on schedule, but produced an accuracy rate of over 99.5% with no damage to any functional element. The experience gained from this FMS program can be applied to future LM-GES FMS case opportunities.

In-Service Engineering Support Process

LM-GES uses an effective engineering support process to successfully meet the critical demands of the AEGIS system containing over 55,000 line items, and to accommodate the aggressive AEGIS ship deployment schedule. This process includes an on-call engineering assessment and repair team (Ship Assist Team); providing AEGIS Weapon System field engineering support to the Navy In-Service Engineering Agent; organizing shipboard installation teams for Ordnance Alterations; preparing lifetime support engineering change proposals; and quickly responding to fleet problems with systems engineering analysis.

LM-GES' primary success is achieved by providing the end user direct access to equipment and system designers when necessary. A single point of contact from the AEGIS life cycle program directs assets including approximately 600 experienced personnel. LM-GES' In-Service Engineering support organization has easy access to collocated Naval Systems test facilities, Engineering staff, and Production organizations as well as the Navy's Combat System Engineering Development Site. These facilities provide for modeling, simulation, and resolution of unresolved ship problems. If necessary, consultation with or actual ship visits by the original system and software/hardware designers are conducted.

Interactive Computer-Aided Provisioning System

The Interactive Computer Aided Provisioning System (ICAPS) is a Government-owned, computer-based, automated system used for processing Provisioning Technical Documentation (PTD). It was designed and is supported by the NAVSEA Logistics Center. PTD was originally prepared manually by the contractor and manually input into the Ships Provisioning System by the In Service Engineering Activity and Navy Inventory Control Point. Hard copies were exchanged until all data was validated which required large volumes of paper, slow processing time, and high costs.

Using ICAPS, the PTD is processed on a PC at the contractor's facility, transferred to the In Service Engineering Activity for review, then transferred to the mainframe at the Navy Inventory Control Point. All data transfers are electronic.

LM-GES has teamed with ICAPS programmers at the NAVSEA Logistics Center to enhance the program to upgrade each release of ICAPS. LM-GES enhancements have been incorporated into each new release. LM-GES has reduced the previous 282 manhours to develop a 3,000 line item Provisioning Parts List to approximately 245 manhours.

LM-GES Competitive Initiative

A significant factor in LM-GES' TQM success is the result of an LM-GES and International Union of Electronic, Electrical, Salaried Machine and Furniture Workers (IUE)

Competitive Initiative. This initiative involved empowering employees and implementing changes to improve the business quality process, comply with customer requirements, and achieve total mission success.

In 1989, as defense cuts were initiated, competition increased, and customer requirements became more demanding, LM-GES began downsizing by flattening the organization from seven layers to three. Communication between labor and management was from the top down, and the atmosphere was one of uncertainty, fear, and mistrust. Corporate plans were to outsource several jobs and in November 1991, more than 400 layoffs were anticipated. This situation led to an unprecedented partnership between LM-GES and the IUE as both sides realized they had to work together to remain in business.

To implement the changes, LM-GES established a cross-functional steering committee to provide direction. Steps were taken to benchmark with others considered the best such as Cadillac and Steelcase. Eventually, union-led work center design teams were formed and educated in business metrics. They were also provided with communication and team building skills. Workers were not only welcome to learn other tasks, they were educated in the importance of these tasks for the system. Employees soon learned their roles in the LM-GES mission.

Goals were set and expanded to provide focus on continuous improvement. Initially the partnership focused on reducing assembly cycle time by 50% and reducing manufacturing cost by 25%. The next step was to reduce scrap and defects by 40%. To achieve these goals, LM-GES listened to new ideas and facilitated implementation; lines of communication opened; and a flowdown process was established so that all employees at LM-GES knew the business plans discussed during weekly stand-up meetings within 48 hours. In addition, LM-GES town meetings and operations outlook sessions allowed employees to communicate with management on issues. Teams became involved in implementing new systems. One team changed the design layout of the manufacturing area. When another team encountered hardware problems from a supplier, a periodic video teleconference meeting was scheduled so operators could directly speak to suppliers and share first-hand information. This leading edge concept called "Floor-to-Floor" communications became a weekly operation for one work center team.

After the LM-GES/IUE partnership was formed, LM-GES reduced touch labor by 26%, inventory by 80%, defects by 92%, and scrap by 81%. The company found increased occupational flexibility by reducing 26 job categories to 4. Perfect attendance increased from 4% to 15%. Grievances were reduced from 281 to 12. Lost work days from injuries on the job were reduced from 2155 to 600. In doing so, workers performed a variety of tasks rather than the same task repeatedly, as over 30 non-traditional roles were created with union employees in salaried positions.

These efforts culminated with LM-GES being named one of America's Best Plants by *Industry Week* in 1994. It also won the 1995 New Jersey Quality achievement award which is based on Malcolm Baldrige National Quality Award criteria. But LM-GES and IUE maintain that the real benefit is the attitude of the workforce.

Performance with Compliance Program

LM-GES established a Performance with Compliance Program in 1991 as a comprehensive training program to systematically disseminate information on critical compliance topics. Designed as a extension of Lockheed's corporate Ethics Program, the Performance with Compliance Program is guided by an LM-GES ethics officer working with the company's audit and ethics committee and legal counsel.

Each year, topics of compliance interest are established, and technical experts identified for each topic. The Performance with Compliance Program publishes information pamphlets with quizzes, and employees are encouraged to read these pamphlets, complete the quizzes, and enter their answers in a drawing. Prizes are awarded to those employees whose names are drawn from a pool of correct entries. The Program also produces interactive video training modules addressing 26 areas of compliance – six of these interactive video modules are mandatory for all employees.

This Performance with Compliance program has been successful, producing enhanced compliance awareness throughout LM-GES. To date, 3,000 employees have completed the mandatory modules and 39,000 supplemental modules, averaging 13 total modules per employee. In addition, LM-GES has shared this program with other companies through the Defense Industrial Initiatives.

Process Improvement Road Map

During the early stages of the LM-GES Competitive Initiative, many improvements and new processes were implemented as the company embarked on its quality journey to achieve process improvement and enhanced employee involvement. These new tools included SPC, Continuous Process Improvement teams, process certification, design teams, and effective training programs. This "tool kit" has evolved steadily since 1988 (Figure 2-11). It soon became apparent that the process improvements needed to be formalized; therefore, a Process Improvement Road Map was developed (Figure 2-12) to chart the company's approach to continuous process improvement while creating a highly-involved, empowered-team environment.

The Process Improvement Team Road Map is one of the key enablers of the LM-GES Competitive Initiative. There

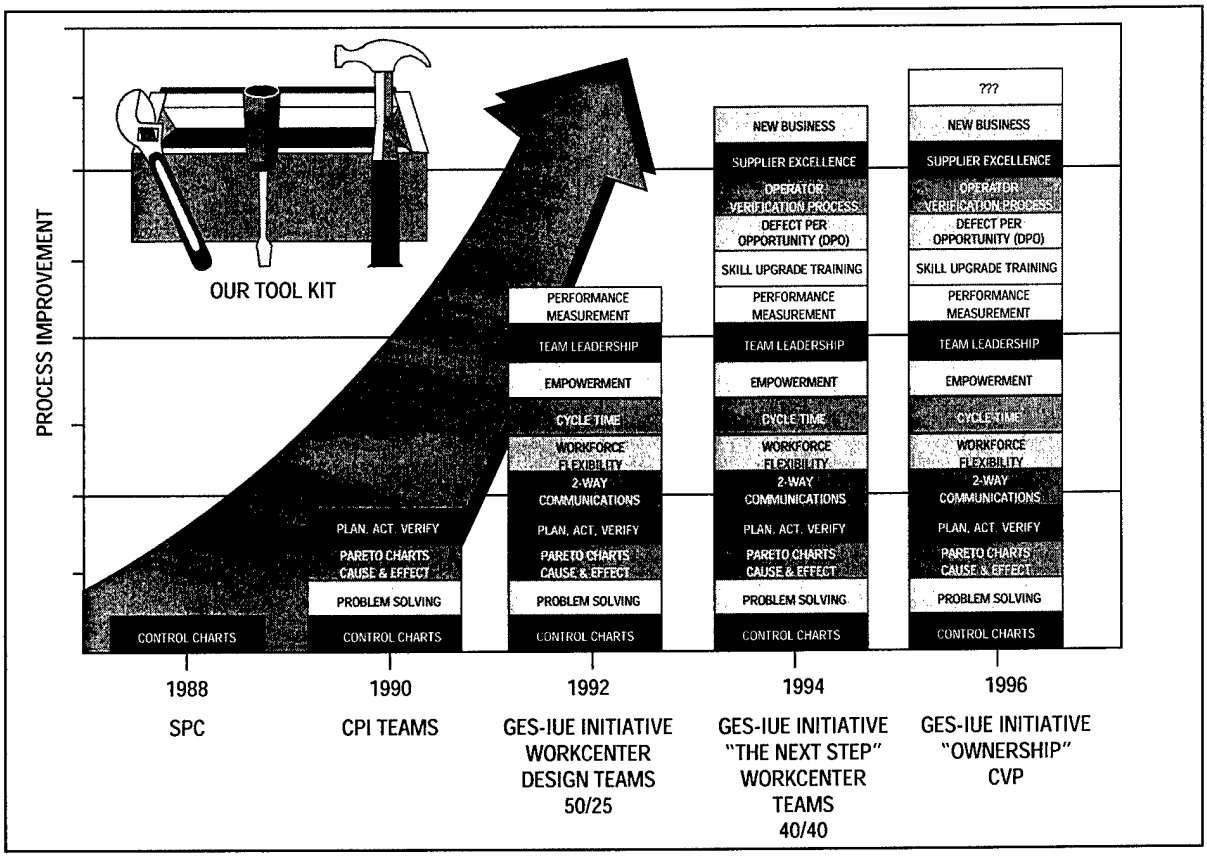

Figure 2-11. Process Improvement Team Tool Kit Evaluation

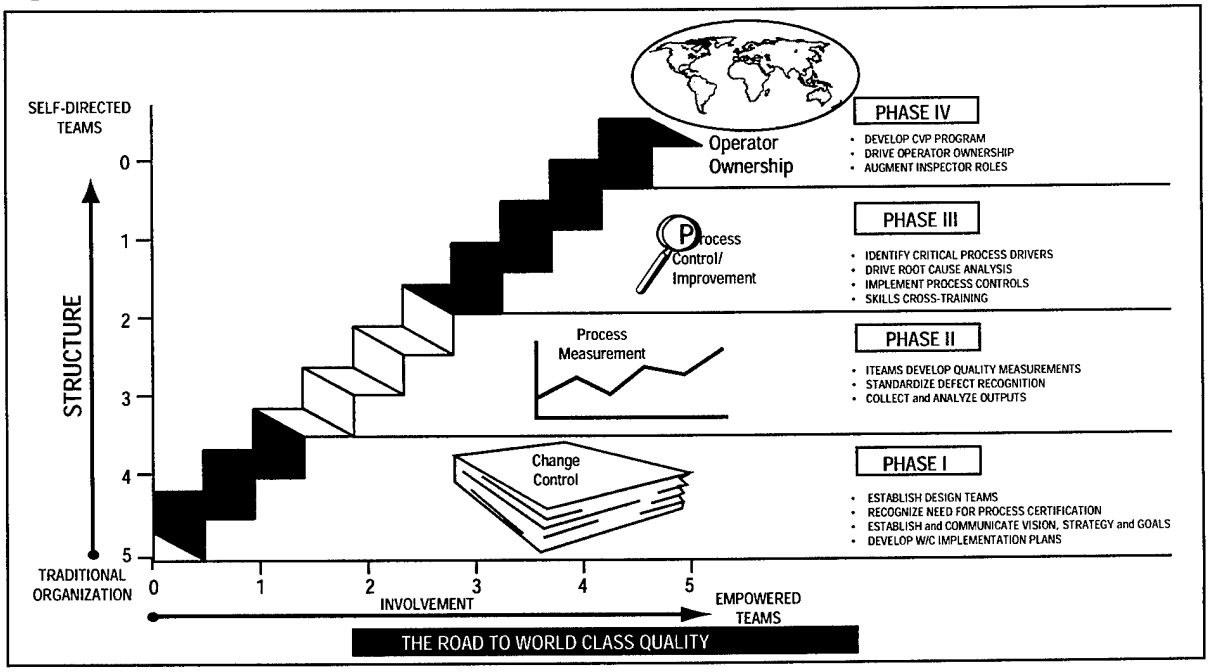

Figure 2-12. Process Improvement Team Road Map

are four phases structured to move the organization from the highly structured/low involvement traditional organization toward a high involvement, unstructured organization populated by self-directed, empowered teams. Phase I has been completed. This phase was one of change control during which teams were established, processes certified, vision and goals were defined and communicated, and plans were developed and implemented. Phase II was the process measurement phase in which teams developed quality measurements, standardized defect recognition, and collected and analyzed outputs. A few teams are still in this phase. Most of the teams are currently in Phase III performing process control and improvement. These activities include identification of critical process drivers, root cause analysis, process control implementation, and evaluation of skill training requirements. Several teams have reached Phase IV which is full operator ownership of processes and equipment and self direction.

By following this road map, teams at LM-GES have reduced critical manufacturing process cost drivers and improved process efficiency through operator involvement, operator improvements, and operator ownership. These efforts have produced a 26% reduction in touch labor, an 80% reduction in inventory, a 92% reduction in defects, and an 81% reduction in scrap. This effective strategy has been well executed and has produced a highly involved work force committed to continuous improvement.

Self Audit Program

LM-GES initiated the Self-Audit Program, an ISO 9001-based continuous self-assessment process of all company business functions that stresses the implementation of preventive action, oversight by council, and visibility by executive management.

Prior to implementing this program in 1990, only LM-GES products were inspected, with little or no self-inspection of the company's business aspects. The traditional practice was not to prevent problems, but to take corrective action on problems as they became visible to the DPRO. This approach produced a large volume of DPRO Corrective Action Requests, averaging more than 100 per year.

When the Self-Audit Program was started in 1990, it required only participation of deliverable product business functions, Operations, Product Assurance, and Material Acquisition. The program followed a formal, systematic, continuous self-assessment process that stressed problem identification and corrective actions, and the implementation of preventive actions as required in ISO 9001.

Self-audits take place in some business functions on a monthly basis while other business functions are audited weekly. A key component of the program is the multifunctional Self-Audit Council consisting of functional managers or representatives and the DPRO. The Council provides program oversight with the focus on continuous improvement. Visibility to executive management – including the president of the company – occurs by monthly status reports and presentations.

The program has proven to be a useful and powerful tool for identifying areas requiring improvement and the need for formal executive focus. Since the program's implementation in 1990, it has been expanded to include all GES functions including Business Development, Engineering, Finance and Contract Practices, Human Resources, and Program Management. The result of this business-wide continuous self-assessment is reflected in the average number of DPRO-written Corrective Action Requests per month that have been reduced by more than 200% (Figure 2-13).

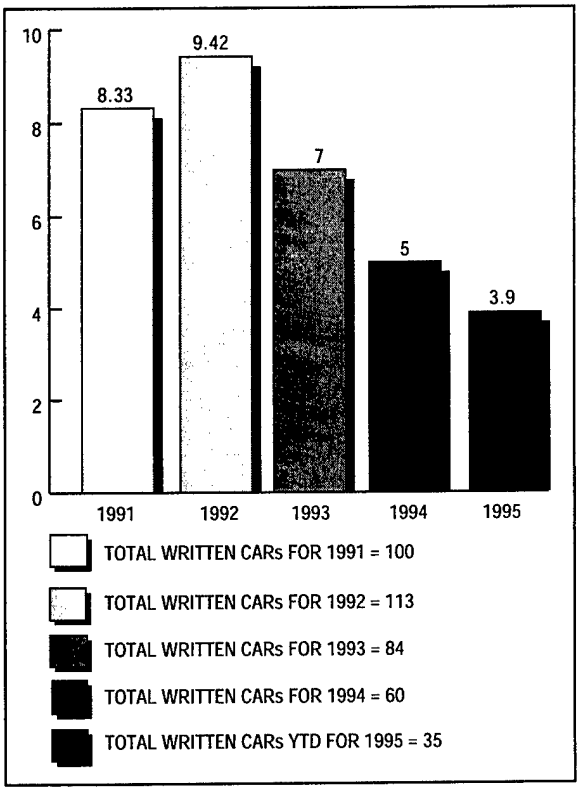

Figure 2-13. Average Written CARs per Month

Technical Evaluation Group Organization

The Technical Evaluation Group (TEG) Organization at LM-GES draws from its resident expertise to provide technical review, analysis, and recommendations of other contractors' proposed engineering changes to the AEGIS combat system.

LM-GES has a dual role of a manufacturer of major system components and an integrator of the AEGIS combat

system containing major components from other contractors. Any changes in components by LM-GES and the other contractors can affect the system. LM-GES has been tasked by its customer to review all changes proposed by other contractors, provide analysis, and submit recommendations. Because of its dual role of manufacturer and integrator, LM-GES can draw on the already existing expertise and processes resident in its organization. The TEG Organization was established specifically to manage this task because of the complexity and magnitude of the system.

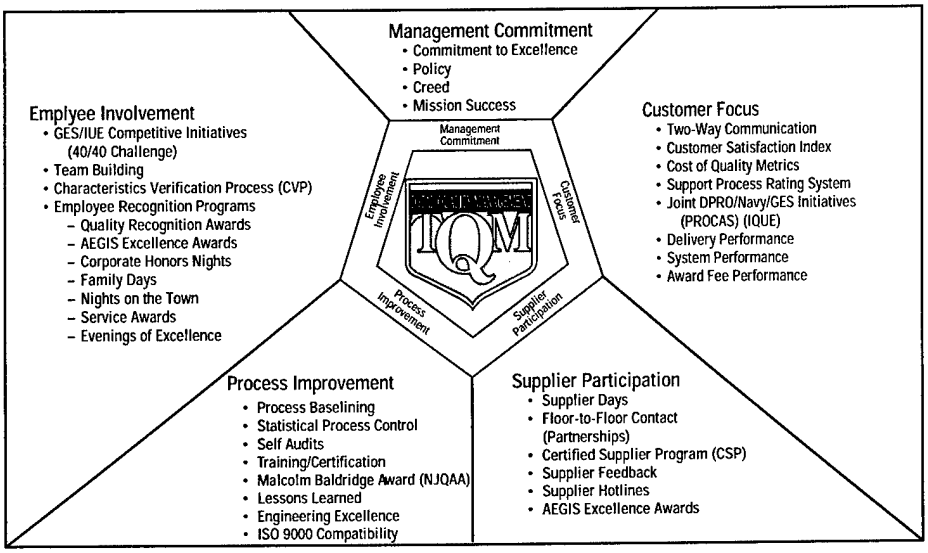

Figure 2-14. TQM Model

The TEG works directly with the customer and has direct access to all LM-GES engineering organizations in support of its task. These organizations include Element Systems, System Interface, Test, Safety, Operations Manning, and Standards; and Life Cycle Organizations such as Integrated Logistic Support, Computer Base Programming, and Configuration Projects. The process provides for a multidiscipline review of proposed changes of major components for impact on the system. An Engineering Change Analysis report is provided to the customer and includes the background and requirements for a proposed change, the technical approach, a detailed analysis of the proposed change, the impact on the system, site impact, logistic impact, test impact, retrofit considerations, and recommendations.

The customer benefits from this systems engineering approach as it takes advantage of an established expertise of the lead system integrator who quickly provides a reliable analysis at a low cost. As the lead system integrator, LM-GES derives benefit from exposure to proposed contractor changes at the earliest point in the system life cycle.

TQM Management Policy

LM-GES faced substantial challenges in 1991 with over 90% of its sales dependent on an ever-decreasing defense budget. The workforce had been downsized from 5,000 to 3,000, and the company was anticipating substantial additional cuts. To assertively address these issues, LM-GES sharpened its focus and developed a locally-tailored TQM Philosophy.

LM-GES senior management developed this TQM philosophy as a five-faceted culture (Figure 2-14) including the following:

1. **Management Commitment**. Corporate management developed and established a TQM creed that has since been actively and verbally reinforced.
2. **Customer Focus**. Customer focus includes a two-way communication process, customer satisfaction index, cost of quality metrics and numerous other initiatives.
3. **Supplier Participation**. Supplier participation initiatives include supplier days when suppliers come to the LM-GES facility to discuss all aspects of business including supplier business forecasts and issues. LM-GES has also developed a "Floor-to-Floor" contact partnership where shop floor personnel call or meet through video teleconferencing with shop personnel from suppliers. The Certified Supplier Program has expanded to over 200 suppliers since 1993 and allows materials to be delivered directly to the LM-GES production line without receiving inspection.
4. **Process Improvement**. The focus on process improvement has been a major shift from an inspection system to a prevention-based system. LM-GES developed strict process controls and worker/process certifications that can not be changed without review board approval. The company has also instituted SPC and self audits. The Malcolm Baldrige Criteria has been used to assess the process improvement, and the company was awarded the Baldrige-based New Jersey Quality Achievement Award in 1994. In addition, LM-GES has been registered to ISO 9001.
5. **Employee Involvement**. Employee involvement has been a key to the LM-GES TQM philosophy. The management/union Competitive Initiative, move to

team-based management, characteristic verification process, rapid communication flowdown and extensive employee recognition have all made a substantial contribution to the success of the LM-GES TQM philosophy.

The initiatives began in 1991 and are continually being developed. Since that time LM-GES has shown substantial improvements in all areas. Productivity is up 64%, work in inventory is down by 80%, manufacturing costs have been reduced by 25%, scrap and rework are down 65%, cycle time has been cut in half, component yield has risen to over 99%, and system on-time delivery is now 100%.

Section 3
Information

Design/Test

AEGIS Combat System Engineering Development Site

LM-GES and the U.S. Navy developed the AEGIS Combat System Engineering Development Site (CSEDS) for system development and integration testing of the system's computer programs. For more than 20 years, the CSEDS has provided complete AEGIS Combat System capability for support of the lead ship, with any necessary evolution for support of follow-on ships. The CSEDS site is equipped to support the level of testing that is underway.

The CSEDS contains many pieces of the actual equipment in the ships, as well as simulators and emulators, and is used for many types of testing. It has the capability for comprehensive combat system configurations using tactical equipment, tactical computer programs, and Navy operators. It is also an engineering test bed for multiple configurations, and has the capability for forward fit design/integration validation, backfit/ORDALT proofing and troubleshooting fleet problems. CSEDS is used for exhaustive element test and evaluation that is accomplished using the tactical equipment and tactical computer programs. Testing is completed in context with other tactical equipment and computer programs. The detailed test requirements are derived from the computer program specifications. Multi-element integration testing is also completed using CSEDS. Regression testing to ensure existing functionality is not compromised by new code, is complete, and "free play" is encouraged to exercise the computer programs in unexpected ways. Test protocols routinely include external services such as Navy aircraft that provide communications and radar jamming. CSEDS applications culminate in demonstration and formal qualification testing. AEGIS equipment and firmware modification are validated for production and the computer programs are delivered to the Navy for use in the Production Test Centers and in the Fleet.

CSEDS is also used for crew training for new baselines including tactical team training, individual operations, and maintenance training. CSEDS is the single installation of new AEGIS baselines and sole site for some Foreign Military Sales system development, element operations and maintenance training. The U. S. Navy uses the site for the train-the-trainer courses and for coordinated crew team training.

The CSEDS facilitates thorough system testing prior to delivery to the shipyard, with complete Navy involvement in testing and training. It provides the ability to transition to new equipment and systems; provides facilities to reproduce, fix, and test fleet reported problems; is the only facility to test many different modifications prior to the waterfront; and is the focal point of the AEGIS project activity.

AEGIS Naval Systems Computer Center

LM-GES and the Navy have invested in the future of AEGIS by designing a network (Figure 3-1) to support evolving AEGIS requirements through the NSCC. The NSCC includes an expandable infrastructure architecture to support next generation technologies and provide facilities for adjunct and/or advanced processor design, development, and test.

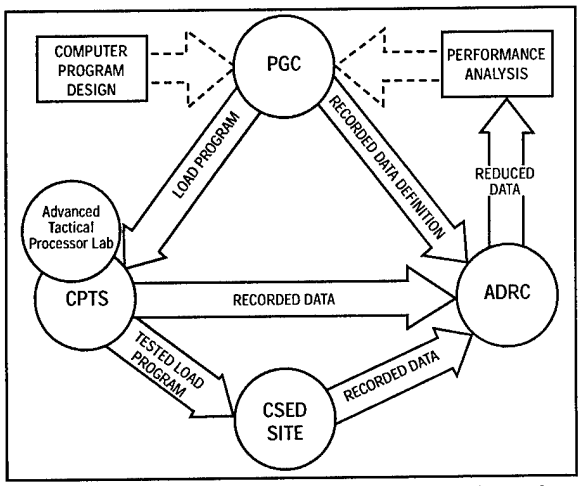

Figure 3-1. NSCC Classified Network Overview

The AEGIS NSCC consists of four main functional facilities (Figure 3-2). The Program Generation Center performs the AEGIS computer program development, computer program unit test, and computer program production. The Computer Program Test Site performs tactical element integration and test, and multi-element integration and test. The AEGIS Data Reduction and Analysis Center performs data reduction, engineering analysis, and simulation. The Advanced Tactical Processor Laboratory performs advanced processor definition, benchmarking analysis, and real-time advanced processor integration and test.

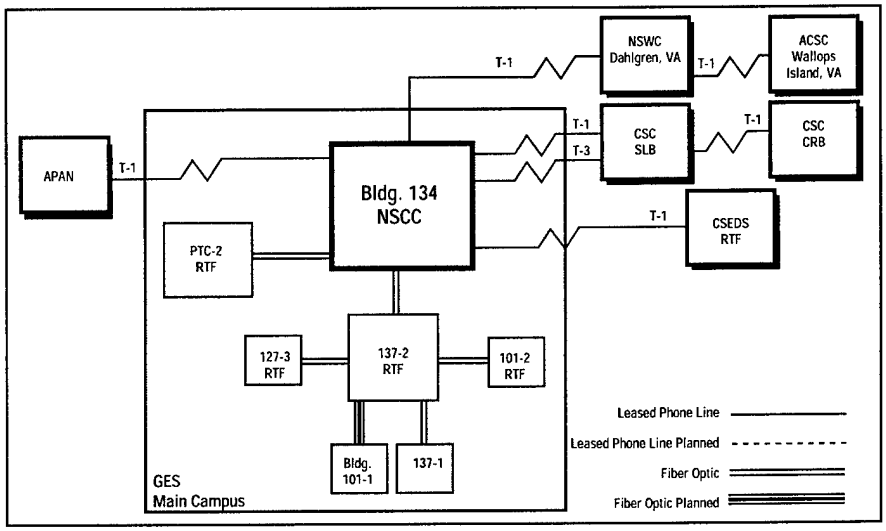

Figure 3-2. NSCC Functional Flow

Since 1993, the NSCC has seen significant advancement. The NSCC is replacing standard Navy computers with commercial, real-time computer systems within a state-of-the-art advanced tactical processor laboratory. The NSCC computer resources allow code development on a centralized VAX cluster or within a distributed UNIX workstation environment. Data reduction and analysis are performed in a distributed UNIX workstation environment.

The NSCC facility is now located on the LM-GES main campus. The Program Generation Center, AEGIS Data Reduction and Analysis Center, Computer Program Test Site, and Advanced Tactical Processor Laboratory are integrated facilities using a high-speed network connection where computer program problems can be tested, problems corrected, recompiled, and retested during a single test shot. The NSCC has communication links to the LM-GES main campus via fiber optic cable, to the subcontractor developer facilities through a 45 Mbit/sec T-3 line, and to the AEGIS Combat System Engineering Development Site and customer facilities via 1.5 Mbit/sec T-1 lines. The network bandwidth capacity allows for full remote access to the NSCC. The following are examples of the improvements made at NSCC (Table 3-1).

Table 3-1. NSCC Improvements

	NSCC Pre-1993	NSCC Today
Target System Processor Speed	2-3 MIPS	up to 600+ MIPS
VAX Cluster Processor Speed	33 MIPS	230 MIPS
Performance Analysis System Processor Speed	16 MIPS	>1000 MIPS
NSCC On-Line Data Storage Capacity	<100 Gigabytes	>1 Terabyte
Time to Update Source Code, Recompile and Retest a Computer Program Load in the CPTS	Several hours	Minutes
Network Link to GES Main Campus	56K bit/sec	up to 45M bit/sec

AEGIS Tools Implementation Committee

LM-GES established an AEGIS Tools Implementation Committee (ATIC) to oversee the selection and usage of software tools involved in designing, developing, producing and delivering AEGIS computer programs. The ATIC was tasked with selecting a configuration management tool for distributed workstation computer program development and delivery environment; replacing outdated nine-track tapes for computer program delivery and archiving; instituting a common media tracking database; and establishing a workstation based CMS-2 computer program development environment.

The results of each of these objectives include:

- The ATIC selected Atria's ClearCase CM tool as the workstation for the configuration management tool as the result of a thorough evaluation.
- A defined and certified process for electronically transmitting computer programs to the customer site. The outdated nine-track tapes for computer program delivery and archiving were replaced using Digital Linear Tape. A future enhancement to the process will include electronic signature capability to reduce sign-off delays.
- A Common Media Tracking Database will eliminate the multiple databases at several sites, each of which has a different tape number for the same tape. The common database will eliminate redundancy of data entry and facilitate retrieval of the tapes.
- A workstation-based computer program development environment now allows CMS-2 code to be developed and tested on the workstations rather than being exclusively VAX based. This provides a simulated Standard Navy Computer test bed and provides a framework for insertion of advanced processor technology into the AEGIS Combat System. The workstations also provide more capacity for development and test.

Initiated in 1992 with eight members, the ATIC has grown to 20 members and has approved 40 AEGIS tools. There are 11 tools under evaluation with five new tool requests following. Minutes of each ATIC meeting are distributed to the AEGIS community, and contain a record

of all discussions and action items including a description of tools being processed; a comprehensive list of all tools approved by the ATIC with a brief description of each; a software version matrix of the AEGIS Workstation Environment organized by project; and copies of all new tool requests submitted.

ATIC encourages concurrent engineering and teamwork by allowing many organizations to participate in the selection process. Using common tools, AEGIS engineers can be trained to be tool experts, and in-house training programs can be provided at a reduced cost over vendor training. The risks associated with integrating commercial off-the-shelf products into deliverable products is minimized. Tools developed for a single AEGIS project are shared by all the program's projects eliminating the need for each project to develop the tool. The use of the shared tools has significantly reduced internal development time of support tools. Costs have been reduced by identifying redundant efforts and coordination of new tool evaluations. The cost of tool purchases has been reduced by as much as 50% through economies of scale purchases.

Automation and Integration of Delivery Documents

In 1988, LM-GES recognized that contract delivery schedules and closeouts were difficult to accomplish. The company had the workload for five systems per year, with 3,000 to 4,000 line items per system. Multiple data sources were producing different types of related delivery documentation; the current system could not keep up with the volume of configuration changes; and traceability to the contractual-as-delivered configuration was difficult. To correct the problem, LM-GES automated the delivery documents such as DD-250s and DD-1149s, and provided a single source for configuration management and delivery documentation.

In the previous system, there was poor coordination between work groups. Diverse PC data sources were used by the different work groups, and the hardware was different as well as the databases for the task. Because there were multiple storage points, a needed change had to be made in multiple places, and individual notification was required for any revisions. Also, conflicts existed between the different sources, therefore causing conflicting data. The company had no way of knowing if a change had been made or whether the same change had been made across the board.

LM-GES reviewed the needs of several activities and integrated the approach to meet the user needs. Automation of the delivery documents was begun by reviewing user needs and the current systems. A database was developed of all the delivery information. Automating the delivery documents has provided LM-GES with shared data that all have access to, a single source for the delivery information, and standardization of the data since it is stored only once. The system also provides for on-line track and retrieve, revisions are made at only one source, and revisions are immediately available to all personnel.

GES's automation of its delivery documentation has provided a single source for configuration management and delivery documentation. The new process has reduced the preparation time for a DD-250 by 95% and the preparation of LM-GES's internal DEM 2401 by 98%. The company is able to prepare a DD-250 at the latest possible time (when the truck is loaded and ready to deliver to the customer), thereby using the most accurate data and minimizing revisions. The accuracy of the DD-250s, DEM 2401s, DD-1149s, invoices, and packing lists has increased significantly due to the single data source.

Continuous Acquisition and Life-Cycle Support System Engineering and Laboratory

Systems engineering and laboratory testing have been applied to Continuous Acquisition and Life-Cycle Support (CALS) candidate products at LM-GES since 1994. The CALS goal of a Contractor's Integrated Technical Information Service has been promoted since the mid 1980s, but implementations have been scarce. LM-GES established a laboratory to provide a test-bed for products determined to provide CALS-compliant solutions to various requirements. Testing is being performed in the context of a nine-step, systems engineering, life-cycle process focused on CALS defined inputs and outputs. Figure 3-3 provides an overview of the equipment in the LM-GES CALS laboratory and its connection to other facilities.

Systems engineering and laboratory testing help provide and demonstrate the benefits of five main goals or objectives which include developing corporate concurrent engineering programs; providing a foundation for an FY96/97/98 Production Request for Proposal citing CALS; and accelerating migration within LM-GES from paper documentation to digital databases. Transitioning from manual (paper) documentation to automated (digital) forms of reference data increases quality, reduces cycle time, and cuts costs.

Benefits for LM-GES to date include four valuable laboratory activities and three examples of streamlined processes. The laboratory enables development of applications independent of operating systems, and more realistic testing of software on hardware available to the end user. It also enhances analysis of potential commercial off-the-shelf products, and provides a valuable training facility. The target process durations for ECP development, drawing delivery, and technical manual authoring have been cut by more than 50%.

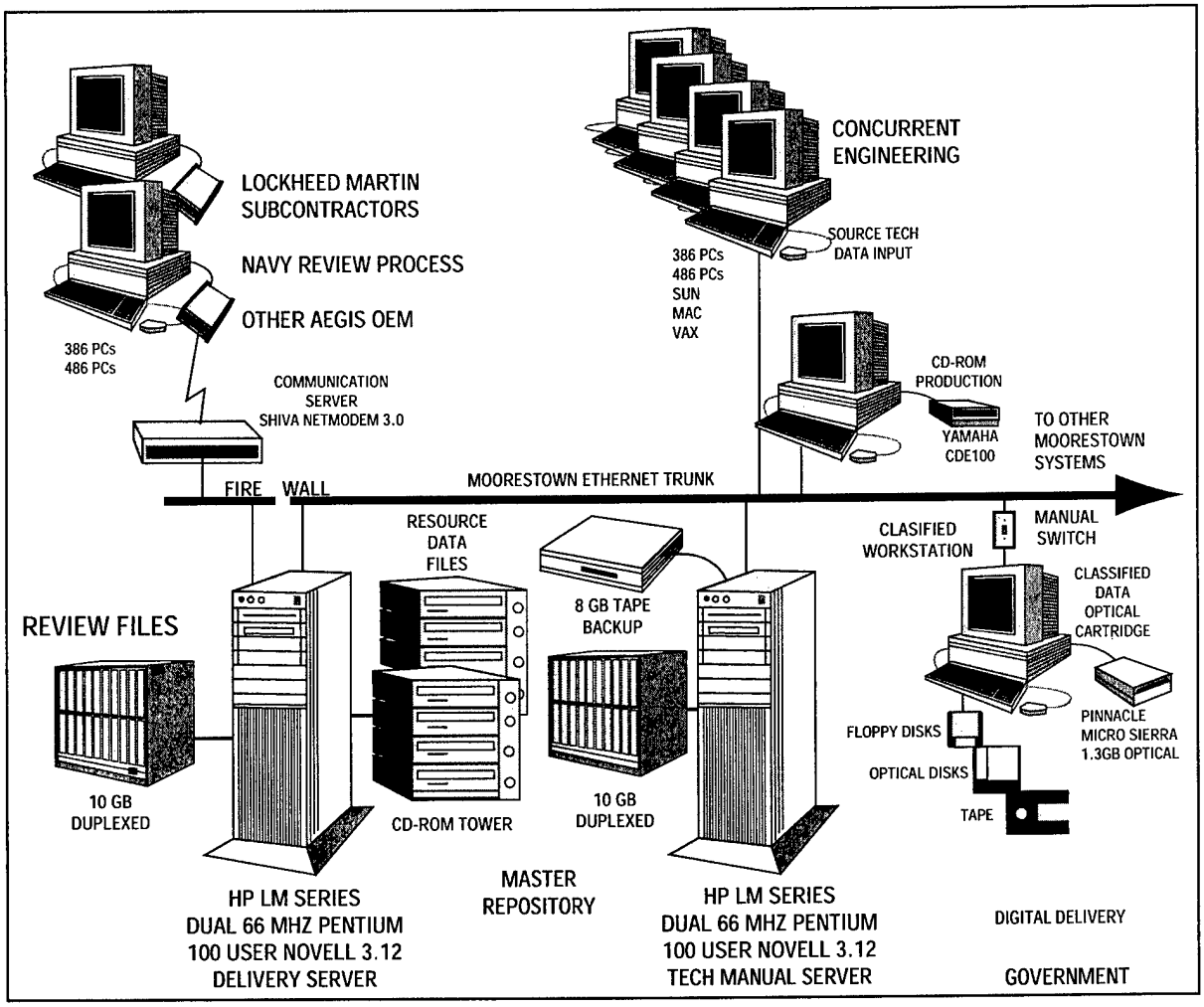

Figure 3-3. Mini-CITIS System Concept of Operation

Combat System Three-Dimensional CAD Design Tools

LM-GES began using advanced visualization CAD tools for mechanical prototyping in 1991 in response to the AEGIS program goal to use three-dimensional CAD tools and the requirements of standards developed under DDG 51 leading to PDES/STEP implementation.

LM-GES worked with the PMS 400 program office, Bath Iron Works, and the Ingalls shipyards to develop a geometric contour model (wire frame) of a DDG 51 Class ship using common CAD tools and database. LM-GES then developed library part pages that model various ship weapon systems. These library pages could be pulled up from the library database and redesigned from the already existing AEGIS Class ship model. This allowed data to be generated once and then reused, eliminating the database exchange use which was fragmented and only done on an as-needed basis.

LM-GES's unique approach to CAD now takes this redesigned model and performs virtual prototyping. The redesign can be reintegrated with the ship through CAD animation to predict its impact. For example, Topaide Design, moving equipment from one location to another on the ship, hull extension, radar beam interaction/interference due to weapon system changes and hero surveys, ease of maintenance, and human interaction with various ship interfaces can all be viewed as a complete integrated system. Viewability is the key feature of LM-GES' approach to CAD. This efficient use of CAD viewing allows for drawings to be easily developed in current commercial/military formats. The library part pages could eventually replace Installation Control Drawings.

Virtual prototyping benefits include reduced design cycle time from weeks to hours, which in turn reduce manpower by more than 50%. This data can be used for the total life cycle support.

Computer Program Product Improvement Committee

The Product Improvement Committee (PIC) was formed in 1989 to review escalating problem reports. The initial PIC recommendations increased management control and insight by forming a Software Implementation Board to assess what was right and what was wrong in the implementation process. The STARSYS (on a SUN-based Ingres system) for software problem reports was also established as part of an improvement program.

PIC has developed and implemented the strategy for the AEGIS process definition and is a part of every transitional challenge for AEGIS. The PIC team has become the focal point and catalyst for continuous process improvement for AEGIS software development, test, and maintenance.

This Product Improvement Committee team provides better understanding of subcontract issues and provides inputs from a computer programming vantage point. It improves acceptance time and buy-in for new standards and processes, and reduces cycle time to meet multiple, concurrent AEGIS baseline demands. In addition, the PIC team eliminates wasteful dialogue and rework, and enhances the entire team's understanding of the project. The PIC has provided a carefully-controlled and monitored momentum of change to AEGIS.

As a result of PIC recommendations, STARSYS is used by project managers to sell off AEGIS product baselines; a SCRIBE now controls requirements changes with customer involvement, and implements computer program changes within a month; and the SIB maintains a charter and scope to control baseline change.

The AEGIS Metrics Plan is approved by PMS 400 and tailored for each baseline developed by the PIC team. The Engineering Test and Evaluation preliminary tests are provided to developers to work out requirements problems before formal testing. The PIC develops, implements, and maintains AEGIS process definitions. The process definitions developed the AEGIS Standards Improvement Group to oversee process improvement. The process definitions also recommended foundation of the AEGIS Tools Implementation Committee. The PIC oversees tool introduction to the AEGIS life cycle process.

Configuration Change Control for Site Equipment

The AEGIS program has three land-based test sites used to evaluate proposed hardware/software changes. These sites are outfitted with government-owned AEGIS equipment. Temporary changes for evaluation, temporary installation for special cases, and permanent changes to this equipment must be documented for configuration management purposes. To record these changes, LM-GES has developed a Site Change Implementation Notice (SCIN). This notice contains a description of the change, instructions, equipment affected, reason for change, list of related documents, and pre/post test requirements.

The SCIN integrates changes into the AEGIS Status Accounting System database. They are reviewed by the site manager, Navy representative, program management office, and Configuration Projects Site Auditor, and approved by the Navy Technical Representative, site manager, and program management office.

The SCIN helps accelerate the change process and bypass the lengthy ECP/ORDALT process for test of temporary changes. It provides configuration control by linking modifications to the appropriate equipment and documents using the system database.

Design Matrices

As workmanship standards such as WS-6536 and MIL-STD-2000 were invoked on the AEGIS program, LM-GES faced redesign or the addition of drawing notes to drawings where existing designs did not fully comply with the new workmanship documents. The goal was to identify design-related issues as they related to contract requirements, resulting in a work reduction. Redesign on such a large-scale radar system presented unacceptable risk, and even the addition of drawing notes to a system which contains more than 600 PWA types alone was an economic burden.

A joint Navy/LM-GES Manufacturing Specifications and Standards Committee developed Design Exception matrices which identify and describe design-driven non-compliances. Examples of design matrix items include unusual component mounting configurations, modified preheat profiles or extra time to solder certain components, and special solder fillet/wetting criteria. The matrices detail alternate standards and limitations. These matrices are controlled by the LM-GES Quality Engineering department. An internal procedure, OI-3813, *Maintenance of WS6536/MIL-STD-2000A Design Matrices,* is the controlling document. The product must have a positive performance history to be a candidate for listing in the matrix. Proposed changes are submitted to the Committee on a standard form. Various LM-GES departments, local DPRO and Naval Warfare Assessment Center representatives must sign off on proposed changes. If approved, the changed Design Matrix is distributed through the LM-GES Controlled Documents System.

Benefits include elimination of unnecessary redesign and/or drawing changes while maintaining a high level of system performance, and reduced need for program-specific tailoring of the workmanship specifications. Teaming of contractor and customer representatives in the decision

process facilitates communications through LM-GES and Navy communities.

Integrated Product Development Concept

Integrated Product Development (IPD) at LM-GES is being implemented as a systematic approach to integrate systems, sub-systems, equipment design, sourcing, manufacturing, quality, and support processes. IPD maintains a special focus on low-cost, reduced cycle times and robust quality of products implemented through Product Development Teams (PDTs). These teams are cross-functional with responsibility and corresponding authority to develop, produce, and support a product.

The PDT effort was initiated in January 1994 based an outside assessment to implement IPD that stated LM-GES business processes have been developed for production and are not integrated or optimized for hardware development programs. PDTs would support eight keys to a successful IPD implementation. The IPD process provides functional metrics, a process map, a tool map for product integration, a work breakdown schedule standardized template, business systems interface, performance measurements, training guidelines, evaluation, and transition-to-production guidelines.

The IPD process is expected to enhance concurrence in future product development.

LM-GES Calibration Laboratory

LM-GES established a calibration laboratory (Cal Lab) to support maintenance and calibration of automated test equipment used on the production floor. Its mission is supported through the innovative use of personnel, processes, and facilities.

One example of the use of the Cal Lab is the use of a Primary Voltage Standard. Traceability of this standard to the National Institute of Standards and Technology involves an innovative reversal of the exchange and comparison process. Instead of sending the LM-GES instrument to the vendor for comparison and certification, the vendor sends a transfer standard to LM-GES and to a few other facilities in turn.

LM-GES Cal Lab personnel also calibrate automated test equipment such as multimeters used throughout the plant to measure voltage, resistance, and current as needed. These verifications, and calibrations followed by recertification if needed, are performed on hundreds of multimeters without opening the case of the instrument. Personnel also maintain a database of test equipment maintenance and calibration to enhance the quality of these processes. This enables weekly analysis of cycle time, backlog, costs, and effectiveness metrics resulting in spreadsheets, charts and graphs to display trends and trigger quality improvements.

Since these changes have been instituted, LM-GES has realized a 10% increase in capacity, and a 2-to-1 reduction in cost of maintaining the primary voltage standard at LM-GES. The closed case calibrations result in cycle time reductions of one day for each multimeter, thereby reducing the number of multimeters needed by 20% and increasing the availability of the instruments.

LM-GES Design Process

The design process used at LM-GES incorporates lessons learned to avoid pitfalls and major budget overruns. This process encompasses all aspects of the design flow – with review mechanisms – to facilitate development efforts. LM-GES has standardized processes and design toolsets to prevent reinventing proven successful designs and streamline the overall design process. By reusing designs and optimizing the use of standard parts, LM-GES can lower development and procurement costs by buying large quantities of the commonly used parts.

Training programs support this design process flow to ease usability through knowledge for the system design engineers. Concurrent engineering on all levels integrates all aspects in the system, while allowing efforts to be focused forward instead of backwards.

LM-GES Site Design-for-Test Strategy

LM-GES digital circuit designers at the Digital Equipment Center have taken the lead in developing internal testability guidelines and creating a process for enforcing them. This LM-GES Site Design-for-Test (DFT) strategy was developed by the circuit designers when they realized that the increasing complexity of their designs were rendering them practically untestable. This trend was further evidenced by the evaluation of module defect data from recent development programs which also pointed to the need for design process improvements.

The existing LM-GES test strategy was the use of conventional vector card-edge testing using powerful, but expensive, general purpose Automatic Test Equipment (ATE). This strategy required the use of engineering talent to debug the failed modules. A current program was consuming an average of six hours of engineering debug time per failed SMT module. Any new strategy had to involve the continued use of these equipment assets, supplement them, yet reduce the engineering labor hours to support them. In-process testing was obviously needed.

An investigation established that many of the DFT tools already existed. An Omnitester 2512 Manufacturing Defects Analyzer was being used to test power supplies but could easily be used to test modules. The Mentor CAE tool suite used to capture and simulate the engineering designs

with Synopsis synthesis tools and TDS Summit conversion software could be used to create test program vectors from the simulation data. The purchase of Victory software for the Teradyne ATE would allow introduction and use of boundary scan devices and testing.

The cultural changes to the design process were easily adapted. LM-GES DFT guidelines have been established and integrated into the existing digital module design process, and DFT checklists accompany existing design steps. Functional Managers support the new process, and DFT will now be a part of the Hardware Development Plan for every new project. Enforcement of the guidelines has become part of the existing design review process. Completed DFT checklists will be presented at the reviews.

Preliminary results of the new process are very encouraging. Application of the new processes against a through-hole mount design has resulted in an increase in first-pass functional test yield from 86% to 94% and a two-thirds reduction in engineering debug time per failed module.

Microelectronics Processes

LM-GES has developed a number of microelectronic processes due to structuring design guidelines and a common process capability. Design engineering now supports both engineering goals as well as manufacturing goals. There have been two significant manufacturing process advancements at LM-GES as a result of these changes.

1. By 1991, LM-GES realized a more cost-effective method was needed for PCB surface mount microwave component alignment. Bonding microwave components to a PCB required alignment tolerances considerably tighter than required for analog and digital component PCB placement. These alignments were critical to maintaining electrical properties necessary for design bandwidths. However, solder flow could not be controlled without the use of expensive fixturing in a conventional solder reflow process. LM-GES successfully used the printed solder masking to control solder reflow. This process involves printing a solder mask dam – a dielectric material using conventional screen printers or stencilers – in areas on a ceramic PCB where solder reflow is to be confined. The solder dams are then cured and conventional in-line solder reflow is completed. The solder dams restrict the flow of solder to the printed areas. Typical component alignments are now repeatable to within $\pm$0.004-inch (4 mils) without the use of expensive fixturing, allowing for rapid economical changes in circuit design.
2. Another area of concern has been hermetic sealing of Transmit/Receive modules. These modules contain numerous components requiring a large area to protect. The previous sealing method involved localized heating (laser weld) to reflow solder preform along the perimeter of the device. Conventional solder reflow requires heating the entire module to at least 300° C for uniform bonding, an undesirable option in this situation since the microwave components are restricted to maximum temperatures of 250° C. The localized heating solder reflow method for hermetic sealing suffered from high yield losses. In 1993, LM-GES began using different materials better suited for localized heat bonding. A metal lid is welded to the sealing surface of a High Temperature Cofired Ceramic alumina package forming a hermetic seal. The process has a 98% first pass yield as compared to 85% first pass (95% with rework) for reflow solder preform. This also reduces parts count since no solder preform is needed. The sealing surface of the High Temperature Cofired Ceramic alumina package is a molymanganese metallized layer on the alumina package. Since this metallized layer is part of the package, it is not considered a separate part for this process.

LM-GES microelectronics, in structuring design guidelines and using a common process capability, was able to achieve process improvements utilizing already existing materials and tools to solve yield problems. Other benefits include easier application of lessons learned, reduced design iterations, reduced transitional problems from development to manufacturing, and reduced process documentation.

Nearfield Test Facility

The nearfield test facility at LM-GES is used to align phased array antennas with regard to phase angle and measures antenna performance in detail. A laser position servo system accurately measures the spatial position of the test probe in an anechoic chamber large enough to accommodate antennas measuring 15 feet across and 15 feet high. The system individually tests each radiation transmitter and receiver element to determine the electrical path length at each frequency of interest. The measurements determine the signal amplitude and phase at known points and frequencies on a predefined rectangular lattice or grid. A computer then determines the individual contribution of each element to the aggregate by means of Fast Fourier transform techniques. Alignment consists of adjusting the electrical length of each transmission path and each reception path for the best overall performance of the entire antenna array.

The performance specifications for gain, sidelobes, and beam width mandate the use of a nearfield facility such as the one at LM-GES. Only nearfield testing can enable alignment of individual elements. Test times are reduced

compared to farfield tests because of the nearfield's greater computer capacity and bandwidth. Nearfield testing also minimizes the risk of exposure of antennas to the harsh weather associated on occasion with outdoor (farfield) testing. The company benefits financially by having the nearfield facility in the LM-GES plant.

Part Obsolescence Management

LM-GES chairs the AEGIS diminishing manufacturing sources (DMS) working group and steering committee which coordinates AEGIS DMS resolution activities between contractors, the Program Office, logistics, and government agencies. The company has developed its own internal working group to coordinate DMS activity between LM-GES functions such as Engineering, Sourcing, Manufacturing, Supplier Quality, and the AEGIS Program Manager's Office. Parts obsolescence has become a critical issue in today's defense market, and consequently, the LM-GES internal group maintains objectives to identify DMS issues early, avoid production impact, and have a cost-effective and timely resolution.

LM-GES's internal DMS database tracks DMS problems through an internal process and integrates current production status information to avoid production impacts. The new Parts Control System integrates the database and AEGIS priority-one database into a single database. The benefits of this system and the discipline process for handling DMS issues include the earliest possible identification of DMS issues; avoidance of production impact from DMS issues; short- and long-term, cost-effective resolution of DMS issues; evaluation and resolution integration; and inclusion of product longevity as a primary criteria for new design part selection.

Problem Sheet Process

LM-GES applies a Problem Sheet Process to identify Engineering/Documentation, Production/Methods, Producibility, and Material problem areas. Three of the four types stop the production process until the problem is cleared. Producibility problems have no impact on material movement or shipment but may cause changes in production, depending on the problem. The problem sheet is a vehicle for communication and documentation internal to LM-GES.

A problem sheet can be generated by anyone such as Engineering, Sourcing, or Manufacturing, which allows all owners of the process to have input into problem solving. The problem is identified and involves the necessary activities for that type of problem. It is a quick-moving process that highlights the issue and facilitates the necessary response. The problem sheet also provides flexibility to both production and development programs. The originator of the problem sheet always gets feedback on the implementation of the solution or is notified of why the problem is a misinterpretation.

Rapid Prototyping of Electronic Modules

LM-GES has set a goal to rapidly bring new printed wiring module designs to market. Competition in the current market environment requires the ability to build and demonstrate product prototypes quickly. The key to rapid prototyping is controlling the sequential, iterative process steps and coordinating the efforts or personnel who perform these steps.

These steps are detailed as follows:

1. Design of the electronic circuit and the module package must be the first task completed and captured. At least two designers normally develop these designs. The two designs must be compatible, and the circuit and components must fit on the module and the module must fit in the next higher assembly.
2. The printed circuit layout must be designed and routed – usually the specialty of a third designer. Design simulations and analysis are performed.
3. While the layout is being developed, the component parts to build the design must be defined and ordered. The lead time before the parts are delivered constitutes the critical path of the prototyping process. Long lead parts are often not predictable for prototypes because of the small quantities involved, and there is always the possibility that many new parts have no purchase history. The acquisition of the parts usually involves more labor and more personnel than any other process step.
4. Once the layout is completed, the tooling documentation developed by this step must be used to purchase or fabricate the bare printed wiring module.
5. When the unpopulated module is completed and delivered, it must be tested. Test parameters are leveraged from the circuit design data.
6. When all of the component parts are received, they must be tested.
7. The components must be assembled on the unpopulated module, soldered, cleaned, inspected, and possibly coated.
8. The populated module is now ready for test and evaluation by the designers. If any performance problems are discovered, the process begins again.

Design reviews are spread between these steps as gates and, if not also coordinated, may impact throughput.

LM-GES is facilitating and improving its rapid prototyping capability by reducing the design and analysis, procure-

ment, fabrication and assembly cycle times. It is improving the design and analysis times with specification templates, design checklists, design standardization, use of standard parts libraries, and continuous updating of simulation tools using parametric models for thermal, stress, and electromagnetic analysis. The company is then combining the features with seamless data transfers.

Procurement cycle times are being improved by strategic alliances with vendors (blanket purchase agreements) utilization of standard parts, early engineering/sourcing coordination, and special priority (streamline sourcing) handling of prototype material purchases, and receiving operations.

Fabrication and assembly cycle times are being reduced by insourcing some of the processes normally contracted out for non-prototype efforts, maintenance and use of selected stock materials and parts, and the use of standardized processes. A new benchtop prototyping machine – the LPKF ProtoMat 91S – is under evaluation and will machine circuit paths on laminated board stock with virtually the same registration as etching. The same benchtop machine then drills and routes the material to deliver a completed PWB. The machine is bundled with all interface software tools necessary to accept its input data directly from the development workstation.

LM-GES is projecting a 45% reduction in Transmit/Receive module prototype design cycle time and a 63% reduction for analog boards by the end of this year. To date in late 1995, it has realized a 30% reduction.

Software Design Center Software Process Improvement Group

LM-GES established a Software Center Process Improvement Group (SPIG) in 1993 to facilitate improvement at both the organizational and project-specific levels. The company wanted to bind existing project-specific efforts, provide an on-going assessment of the Software Firmware and Software Quality processes, and to facilitate improvements.

The SPIG, a Software Center initiative, recognizes the increasing focus on process improvement by its current and potential customer base. The increasing complexity and scope of software in LM-GES delivered systems required that the company mature the processes used to develop software. The SPIG utilizes the Software Engineering Institute Capability Maturity Model and maintains a goal to institutionalize process improvement activities and achieve Software Engineering Institute Defined Level 3.

The SPIG has a diverse membership from top-level managers to software engineers and consists of one fulltime member and 12 parttime members. The membership spends approximately 60 hours per week on SPIG activities and ensures that process improvement efforts are focused on areas of high return on investment, are appropriate for the contractual requirements of existing projects, and are institutionalized across the participating centers.

The SPIG conducts assessments on projects for Capability Maturity Model compliance. The procedure consists of:

- developing a questionnaire for a Key Process Area;
- conducting evaluation interviews for projects;
- documenting preliminary findings and recommendations;
- discussing findings with projects and their first-level managers;
- documenting high-level tactical plans;
- releasing composite findings and recommendations;
- creating non-project specific operational plans from high-level tactical plans and implementing them;
- providing project-specific recommendations to process leader for creation of corrective action plans; then,
- selecting another Key Process Area and initiating the procedure again.

The LM-GES SPIG has improved its process by realizing that corrective action is a hand-off point, and that facilitation and a closed-loop tracking system are required. The SPIG has also learned that project-level corrective action must demonstrate a tangible benefit in cost, schedule, and quality. Also, assessment accuracy is improved with Capability Maturity Model training, and the scope of process improvement efforts must span the entire project life cycle to provide full benefit.

From these lessons learned, LM-GES has formed a division-wide Software Engineering Process Group in May 1995 to address these issues. This Group will cover all areas within the Engineering department.

Software Project Planning and Management

LM-GES is institutionalizing its Software Center Planning and Status Tracking activities to develop and review software plans early in a project's life cycle. This effort was initiated in 1994 as the result of a review by LM-GES that detailed software planning was not being completed early enough in the life cycle.

The Software Center adopted a standard Software Planning and Status Tracking approach to provide common methodologies across projects, make planning and management assets available for reuse, and identify and reduce risk early in the project life cycle. This approach has been institutionalized through periodic and as-required Software Planning and Software Center Reviews for all projects.

During a Software Planning review, the definition of software goals, processes and methodologies, standards and deviations, task definitions, project organization, schedules, staffing profiles, risk management and metrics

are stressed. Management reviews examine earned value, project and internal milestone and schedule status, accomplishments and plans, risk management, action item status and staffing issues. The Software Center reviews provide a periodic, closed forum for software managers to address status concerns and corrective action. Software planning reviews at the management level are held once a year, and at the project level once a month.

LM-GES estimates that approximately 12 hours per month are spent on software planning reviews at the project level, and that approximately 48 hours per month are spent for Software Center reviews. LM-GES has already seen some benefits in cost, schedule, and quality performance since establishing this process.

Software/Systems Engineering

LM-GES developed an integrated, dual-Center approach to concurrent software requirements specification and software architecture design in 1994 to bridge the gap between its Software and Systems Engineering Centers. The company recognized the need to establish that bridge between the systems engineering and software engineering methodologies to avoid the persistent and expensive risks faced by software projects of late, vague, incomplete, non-testable, and misunderstood software requirements. Using the system/software team process, LM-GES has been able to develop products with a high degree of concurrence and significant time savings for document generation.

Before the advent of integrated software/systems engineering, LM-GES developed system requirements, then passed the software requirements to software engineering with little to no interaction between the Centers. LM-GES developed a Systems/Software Team process that consists of advanced planning, an integrated toolset, management investment, team collocation, a workstation ratio of one-to-one, an orchestrated hand-off and review, and early configuration management.

During the advanced planning stage, personnel are trained for all the processes and tools that will be used during the development. Plans are made for all software engineers to have a workstation with sufficient tools. Templates are developed or used that match the contract CDRLs and Data Item Descriptions. Tools are set up. Local experts for system administration, tools, and networks are made available. If needed, vendor support is also available for proactive vendor maintenance and consulting.

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LM-GES has integrated a toolset that is used by both the systems and software engineering Centers. The toolset – which consists of RDD-100, Interleaf, Matlab, Bones, Requirements Traceability Management, Teamwork, and Mesa – allows LM-GES engineers to document, trace, simulate, model, and provide configuration management for the product requirements.

The hand-off of the requirements from systems to software is accomplished electronically with the use of the RDD-100 tool. The requirements are then loaded into RTM for the software engineers and placed under configuration management control.

LM-GES has learned that having the proper allocation of workstations and resources, as well as strong management, team, customer, and subcontractor support, access to common tools, and available local experts available are keys to this software/systems engineering success. The company reduced the time needed to generate a System Segment Design Document by 56-71% and an Interface Design Document by 40%. Total savings for document generation on the pilot project for document generation was 47%.

Specifications and Standards Committee

In 1991, the AEGIS Program Office implemented a best manufacturing recommendation for the use of joint Navy/LM-GES Manufacturing Specifications and Standards Committee to resolve numerous technical issues of the AEGIS program. An AEGIS contract granted problem resolution authority to LM-GES Naval Systems Engineering, Operations, and Product Assurance; Navy Technical Representatives; and DPRO-Quality in reviewing and implementing recommendations for contract exceptions/deviations to AEGIS contract specifications and standards.

Typical tasks of the committee include:

- coordinating and implementing new specifications and upgrades,
- resolving compliance issues,
- ensuring specification compliance adherence,
- evaluating the impact of critical manufacturing process change,
- monitoring and following up on new specifications/upgrades,
- resolving technical issues through the use of letters of understanding, design matrices, contract modifications, and exceptions/deviations/waivers,
- supporting reliability/producibility initiatives and cost objectives,

- requesting government technical assistance, and
- meeting on a bi-monthly basis with AEGIS Technical Representatives and DPRO-Quality.

Specifications and Standards Committee decisions include application of Design Exception Matrices for soldering and ESD which identify design-related constraints when an old design cannot support new specification requirements. Another decision is an enhanced Defect Library process that documents a common manufacturing process requirement description/interpretation for both government and contractor personnel. This reduces conflicts in interpretation of a problem between DPRO-Quality and LM-GES production. A solderability maintenance plan and an Ozone Depletion Chemical Elimination Program has also been instituted. Future tasks and involvements will address transition to commercial standards, fiber optics and plastic parts issues, and no-clean fluxes.

Benefits include expanded training, improved processes through avoidance of ambiguous contract requirements in manufacturing processes, better documentation/communications, and improved quality/cost. The committee helps reduce costs of rewriting Request for Proposals during the acquisition cycles. This effort feeds directly into process/factory training requirements.

System Engineering Requirements Management and Requirements Analysis

Since mid-1994, LM-GES has used a more controlled method to manage and analyze systems engineering requirements. It is a controlled process that identifies, organizes, analyzes, and manages defined requirements to support well-founded systems engineering decisions. LM-GES adopted the method because the previous practice did not meet the needs that prompted the user request. Some generated responses should have been addressed by the system maintainer rather than the developer, and some user requests were lost.

The first step of the new process converts a user's need into a combination of system elements that address the needs, and concludes with an evaluation of the impact of proposed changes. It provides conformance to the requirements for systems engineering analysis and management. This capability to trace requirements ensures design completeness. The method leads to a natural progression from user needs through user requirements, system requirements, and derived requirements, to implementation of the selected solution. This progression enables the definition of a well-deliberated acceptance testing scheme, and encourages structured, disciplined design. It also improves documentation quality with less document engineering by the designers. Estimated savings on selected projects range from 30% for a functional diagram task to 70% for a radar hardware specification task.

Production/Facilities

AEGIS Naval Systems Computer Program Subcontract Management

In 1990, LM-GES developed engineering processes to establish discipline in all engineering functions and subcontractors in the AEGIS program. This effort was initiated to alleviate considerable disarray of subcontract management.

Previously, subcontractors provided LM-GES with products, but Lockheed Martin did not know how the product was developed. AEGIS subcontractors were under the direction and control of the Computer Program Development office. The responsibilities of the Computer Program Development manager included the development of AEGIS computer program standards, subcontractor's statements of work, control and monitoring of subcontractor cost, schedule, and technical performance, control of computer program development resources used by the subcontractors, direction of computer program change requests for implementation into element computer programs, and management of subcontractor design, code, and test activities through computer program delivery.

LM-GES conducted reviews with the computer program developer subcontractor each month. These reviews consisted of the subcontractor development team's progress; program status; documentation schedules; error/defects in products pinpointed through metrics, schedule, cost and resource issues; and configuration management/software quality assurance concerns/progress/status. These reviews required three full days, and only junior level personnel from subcontractors were involved.

Consequently, LM-GES restructured its subcontractor management process. The computer program developer subcontractor now follows the LM-GES computer program standards, and the subcontractor tailors these standards to the way it does business. Today, GES knows how the computer programs are developed, and disciplined processes have replaced the less disciplined processes. The monthly review now requires half a day, and management as well as junior level personnel from all AEGIS computer program teams participate in the reviews. After the AEGIS monthly meeting, an executive review is held with key management representatives from LM-GES and the software subcontractor. This meeting addresses programmatic and technical challenges in an open forum. It is chaired by the manager of Computer Program Development, and session presentations follow "hot" topics from the AEGIS

monthly session. Contract, cost, schedule, and resources are examined in detail , and the two groups can negotiate to meet schedules.

LM-GES' modification of its subcontractor management process has reduced the time for the monthly subcontractor reviews by 85%. LM-GES has been able to meet the challenges of future baselines through innovative, functional organizational changes and processes. This has been accomplished through assigning a baseline manager for all AEGIS baselines, developing the AEGIS computer program computer center, the AEGIS process improvement committee, the AEGIS standards improvement group, the AEGIS tools implementation committee, and the AEGIS metrics plan.

Automated Surface Mount Assembly Line

In the late 1980s, LM-GES realized a problem existed with the methods of producing surface mount modules. Old standalone equipment could not keep up with AEGIS production requirements. The accuracy of component placement was inadequate; manual material movement created substantial defects; and a 1,1,1 trichloroethane vapor degreaser was used for cleaning. All jeopardized LM-GES' future in the market.

In 1990, LM-GES partnered with the Philips Electronic Instrument Company to develop an integrated surface mount technology line. This effort resulted in LM-GES' Automated Surface Mount Assembly Line (ASMAL) which is capable of meeting current and future circuit designs, increasing production quality, and increasing production capabilities.

These improvements were accomplished by utilizing modern state-of-the-art equipment in several ways. Defects due to handling were reduced by implementing a conveyorized handling system. Placement accuracy and parts handling flexibility were improved by using a three-station, pick-and-place system with a flexible cassette loader. Changeover times were reduced with a fully integrated engineering file download direct to the placement equipment. The reflow process window was opened by replacing the existing vapor phase and moving hot plate reflow systems with an IR/forced convection system with a nitrogen atmosphere. Corporate ozone depleting chemical reduction goals were met by replacing the 1,1,1 trichloroethane cleaning system with an in-line semi-aqueous system using a terpene solvent.

LM-GES' development of the ASMAL line and establishment of SMT design criteria have resulted in significant improvements. The process has improved cycle time by 15%, reduced touch labor by 45%, decreased scrap by 87%, and increased aggregate yield 12% while defects per unit dropped 97%. The line can handle a variety of manufacturing/design challenges such as ceramic or organic board materials, and single or double-sided designs.

Chemical Control

LM-GES developed a closed-loop chemical control program to address the proliferation of chemicals and low-level regulatory compliance. The new chemical control program has strict controls to review and regulate the ordering, use, storage and handling of all chemical materials to regulatory requirements. Chemicals now undergo a pre-approval review by the Chemical Control Committee, and only those chemicals with Environmental Safety and Health approval can be purchased. This review not only considers impacts on air and water permits, but is a proactive policy of reducing chemical types and quantities.

Proper management and control of chemicals at Lockheed Martin has reduced the active chemical inventory, reduced ordering, and is helping limit personnel exposure.

Energy Management System

Recognizing that many buildings, equipment, and processes were outdated or inefficient, LM-GES initiated an aggressive energy conservation program in 1993 to reduce the annual utility costs. Although cost/competitiveness were primary reasons to conserve energy, there were other factors at LM-GES such as natural resource conservation, pollutant reduction, community involvement, and an enhanced work environment.

The Energy Conservation Program is focused around a rolling five-year plan that is updated yearly to account for changes in technology and the business environment. This program is a coordinated effort between the Engineering and Maintenance departments with input from all related trades. Building retrofits, automatic power-down sensors, and area demand meters are used in combination with an intelligent energy management system to conserve energy. Augmenting this program is the employee awareness program, the EPA Green Light Program consisting of training courses, workshops and innovations, and utility partnerships. Under the utility partnership, LM-GES receives periodic rebates and subsidies. In other cases, it bypasses the utility to get the lowest rate on various utility products.

Since the implementation of the energy conservation program, the lighting retrofit effort which involved replacing lamps and ballasts with newer products has resulted in lower energy use. Building 137 had a 355 KW demand before retrofit and 295 KW after retrofit. Similar reductions can be expected in other areas and buildings of LM-GES.

High Density Interconnect Multi Chip Module Technology Transfer

When faced with design requirements for higher performance electronics at reduced size, weight, and cost, LM-GES transitioned developmental technology developed by GE Corporate Research and Development into production. The technology is called High Density Interconnect, an advanced technology for producing multi chip modules with performance, cost, and reliability advantages in applications from DC power through microwave.

High Density Interconnect begins with a ceramic substrate which is milled out to accept various chip sizes. Chips are placed in the indentations and a dielectric material is laminated over the chips. Vias are then laser drilled through the dielectric to pads on the chips. Copper is next electroplated over the assembly, photo resist is applied over the entire surface, then imaged and etched to form the conductor pattern. The process is repeated for the desired number of layers. Assemblies of up to five layers have been constructed with three layers as typical. This approach allows for minimum chip-to-chip spacing and potential for the lowest profile three-dimensional stack.

The technology allows for semiconductor style batch processing, providing a very low cost multi chip module approach. LM-GES predicts an overall manufacturing cost improvement of up to 20% over conventional chip and wire technology. The elimination of wirebond interconnections should produce reliability improvements of up to 33%, and the near edge-to-edge component placement should provide size/weight improvements of up to 50%. LM-GES anticipates replacing the ceramic substrate with plastic or chip-on-flex as the lowest cost multi chip module model yet proposed.

LM-GES maintains that this approach provides a significant competitive advantage over standard interconnect technologies. While only a small number of production assemblies have been manufactured, the company anticipates producing more than 1000 modules using this technology in 1996 and have a total manufacturing capacity of 30,000 modules per year.

Lock-Out/Tag-Out Procedure

LM-GES determined that its existing general lock-out/tag-out procedure for over 250 pieces of equipment was not detailed enough. Therefore, individual log-out/tag-out procedures were developed for equipment that is hard-wired, fed through circuit breakers, or supplied by multiple types of power. The procedures were developed since national statistics show a majority of serious industrial injuries are related to poor management of electrical hazards. OSHA also requires written procedures whenever there are multiple power sources or when a single lock-out device will not completely de-energize or deactivate the machine or equipment.

The detailed procedures specify how to remove power, pneumatics, and air connections as required. These procedures include diagrams of the equipment illustrating the log-out/tag-out points, and indicating the specific steps to be taken to achieve log-out/tag-out status. Both the shop supervisor and the maintenance supervisor must lock-out the equipment. The procedures also have the necessary steps for removing lock-out status and restarting the equipment. The procedures are indexed by building and are supplied to the supervisors of all employees who may be affected. A database, maintained by the safety leader, can easily accommodate new equipment or relocation of existing equipment.

The employees have access to the procedures so maintenance can be safely performed. The procedures also provide an easily auditable source of compliance with OSHA standards.

Long Range Facilities Planning

A Long Range Facilities Plan was initiated at LM-GES at the end of 1994 to plan for the changing business climate and accommodate flexibility. This effort was also needed to increase the ability of the organization to be competitive.

LM-GES facilities planning was previously conducted on a short-term basis with little emphasis placed on long-term goals. In some cases, the company could not procure needed equipment because different groups did not share information. A good planning tool was needed to promote an understanding of the direction the facility was headed. Also, the planning process needed to be open to all team members who were responsible for the plan's implementation.

The Long Range Facilities Plan is a five-year plan, updated annually, with inputs from many sources. The plan addresses major capital expenditures, and detailed planning is provided for facility improvements with justification provided for major expenditures. Prioritized needs of the facility are presented so management can evaluate the impact of capital expenditures on the overall operating expense. All information is presented in the company's Facilities Five Year Plan.

The Long Range Facilities Plan furnished information to facilitate the optimum use of available funds while ensuring continuous profit through uninterrupted facility operation.

Manufacturing Execution Systems

In a continuing effort to improve and automate its manufacturing processes, Lockheed Martin GES is developing a

Manufacturing Execution System which will integrate five major areas.

Developed and implemented in early 1994, the Shop Management and Realtime Tracking System provides electronic labor collection, time, and attendance information. It also provides actual labor hours feedback to MRP and other systems. There are several systems currently under development including a work-in-process management system, Quality reporting system and Computer-Aided Process planning system to support management reporting; and a Capacity Requirements Plan to provide capacity analysis. All of these systems will be integrated with a user interface and a Reports and Inquiries system to provide control and reporting over Quality, Production Control, Shop Operations, and Manufacturing Engineering. The benefits of the system will be an efficient business process developed and run by the users.

Material Measurement Book

LM-GES developed a Material Measurement Book, a compilation of critical process and performance measurements, to provide status using established control limits since standalone measurements were not agreed upon and were at times conflicting.

An efficient, economical, and productive means of conducting business is established in the Material Management and Accounting System standard delineated in DFARS 242.72. As part of its self-assessment program, LM-GES developed a continuous surveillance mechanism through its system and process performance measurements to alert all levels of management to potential problems. Management reacts quickly and efficiently to address and correct these issues. The result is a material system that is compliant with the Material Management and Accounting System standard.

Cross-functional measurements of critical processes are collected monthly to provide a continuous surveillance of critical processes and performances. Monthly management review meetings are held to analyze ongoing trends and develop corrective actions as required. The employees participate in developing new measurements that they see can be beneficial. A single point of contact coordinates the measurement and data collection that can be validated for consistency.

LM-GES analyzes critical processes and performance on a continual basis. The trend data provides validation of expected results, or when a problem arises corrective action can be taken.

Material Review Board Process

An effective MRB process has evolved since 1992 at LM-GES to address difficulties in controlling defects. Each defect had previously been reviewed separately, creating redundancy and time delays. Preliminary Reviews (PRs) were performed by appointed Quality Assurance personnel who were selected based on experience only. LM-GES and DPRO maintained separate databases to report MRB activity. This repetitive reporting effort was often inconsistent and created delays and confusion. Standard repair limitations in place were established by subjective means, and were often not realistic allowing too many repairs or denying legitimate needs. In addition, this program did not support the LM-GES continuous defect reduction effort.

The new process (Figure 3-4) is three tiered with preliminary review requirements, MRB activity and reporting, and

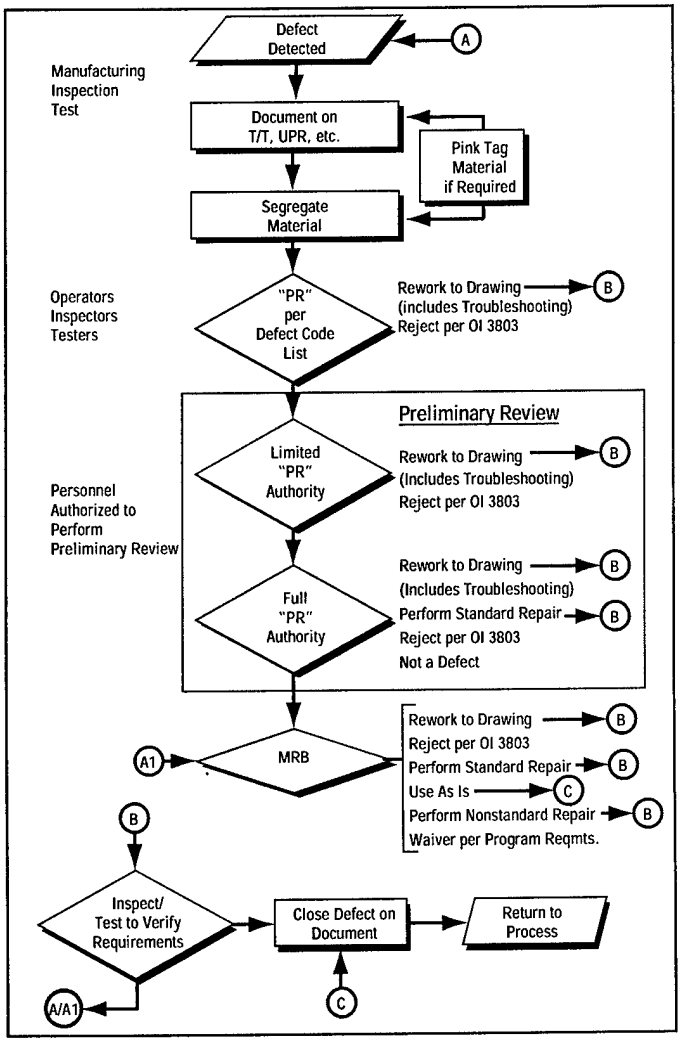


Figure 3-4. Engineering Process Flow

standard repair approval and limitations. Selected defects still require PR approval in most areas, but PR personnel appointments are based on formal training and written tests as well as past experience. A limited PR authority has been initiated to allow non-QA personnel disposition of obvious reworkable defects. A single database has been developed on the network to satisfy both DPRO and LM-GES reporting needs. Measurement of corrective action effectiveness is based on determination of occurrence or recurrence as defined by MIL-STD-1520C applied on MRB actions only.

A procedure and Non-conformance Report format support pre-approved authorization for any reason identified by the MRB. Standard Repair Instructions are submitted to the MRB on a special form. Standard repair limits are statistical or fixed, and are derived using valid statistical methods applied to historical data. When limits are exceeded, Standard Repair Instruction use is allowed to continue while a process cause and corrective action are identified and submitted to the MRB.

LM-GES better utilizes resources, encourages ownership of the processes, eliminates redundancy, and minimizes production delays. Data is not inflated by Standard Repair Instruction activity and continuous improvement is realized.

Mentor-Protege

The Department of Defense (DOD) established the Mentor-Protege Initiative to provide incentives to major DOD contractors to assist small disadvantaged businesses (SDBs) in enhancing their capabilities to perform as subcontractors and suppliers. Objectives include increasing the overall participation of SDBs under DOD contracts and fostering long-term business relationships between SDBs and major contractors. The AEGIS program recognizes the benefits of the SDB program and has funding to support this initiative by requiring an SDB program in AEGIS prime contracts.

The program benefits both the mentor and the protege. The protege benefits from the prime's expertise and resources which help it develop into a proven, qualified, competitive business. It provides a vehicle to transfer excess equipment for increased protege capability. It also creates heightened visibility with internal and external customers of programs or projects to contract with SDBs. The program positions the protege to compete for work on programs of other major primes and enhances multifunctional team participation.

In 1994, LM-GES identified Pioneer Machine and Tooling Company as a protege. This 26-person company is a small machining firm founded in 1985. The project selected for Pioneer involved refurbishment of off-array waveguide skids (used in shipping) as a cost takeout opportunity on AEGIS. Waveguides skids were previously scrapped after use and new ones purchased. Having the skids refurbished by Pioneer for reuse provided substantial savings to the AEGIS program. LM-GES helped Pioneer purchase CATIA (CAD/CAM) software for engineering enhancement and helped the company acquire manufacturing equipment such as a high speed saw, compressor, and punch press. LM-GES also qualified Pioneer employees in MIL-W-8604A for aluminum welding; trained employees in SPC, Shop Floor Control, and business accounting; and updated the company's quality manual.

Since April 1995, Pioneer has delivered three ship sets of refurbished skids. This accomplishment was recognized during a ceremony at Pioneer with representatives of the Navy and LM-GES. Pioneer has since been approved to manufacture a pilot run of the critical AEGIS phase shifter tuning iris. Other prime contractors have taken notice of Pioneer as well. The company has received orders from Boeing and Lockheed ASTRO-Space.

Preventive Maintenance Program

LM-GES recently installed new maintenance software to update an outdated and severely-limited Preventive Maintenance Program. The previous software program had many limitations, was not supported, lacked flexibility, and restricted data input for mechanic feedback or other vital reference information. All tasks were prepackaged, limiting applicability and reporting functions.

LM-GES installed a commercially-available maintenance software program to provide complete tracking for all company and customer-owned equipment. Estimated and actual maintenance time data are now collected for operations performed in any interval from weekly to yearly. The software maintenance system provides data reports to aid in the repair/replace evaluation, thereby minimizing downtime. System flexibility allows customizing production/maintenance work schedules, which is an important aid in planning manpower requirements.

LM-GES' new Preventive Maintenance Program satisfies customer, company, and OSHA maintenance accountability requirements while providing a high level of equipment performance.

Production and Inventory Optimization System and MRP II Manufacturing Systems

LM-GES maintains Production and Inventory Optimization System (PIOS) – a closed loop MRP system – as part of the overall Material Management and Accounting System. The PIOS MRP II System contains multiple modules designed to manage a program from contract to shipment.

The prior system used by LM-GES contained an internally-developed Inventory Management System statically

operated and used by material ordering personnel. In addition, a Production Management and Control System was developed internally and was used by scheduling and production control personnel as an independent planning and scheduling system. The Moorestown Configuration Management, used by Engineering personnel, provided configuration management functions. The Consolidated Purchasing System was a PIOS module modified to meet LM-GES requirements. All systems operated independently with little integration. As a result of the independent operations of this system, status reporting was often inconsistent, measurements were parochial in nature, three different repositories for part master data existed, cost data did not effectively support financial reporting, residual material was unmanageable, and time phasing of material was inefficient.

LM-GES acquired PIOS which was compatible with the aerospace industry. Implementation was unique as all PIOS modules were incorporated with no phase-in needed of specific modules. The system underwent a pilot program and required extensive training and buy-in from the employees. This was a significant effort because PIOS has numerous operation modules including inventory receipts, cycle count, customer order entry and shipping, master production scheduling, stockroom locations, part routing codes, order cost inquiry, prospect inquiry, and other modules that allow the successful delivery of a major system.

The benefits achieved by LM-GES with the implementation of PIOS included cross-functional ownership of all processes, a singular material system, total integration of material processes, increased operating efficiencies, performance improvements, and business assets optimized and cost minimized by the efficient use of inventories.

Solderability Maintenance Plan

LM-GES developed a plan to guarantee that its components would be solderable when needed. Maintaining solderability of electronic components was difficult due to inconsistent lead finish from component vendors or improper storage of components.

The new process divides components into one of four categories. The first category includes components that are shipped from suppliers and are required to meet solderability specifications called out on the manufacturing drawing. Solderability is verified upon receipt. Other categories include parts that are received from suppliers with solderability requirements called out on a purchase order; these parts are also required to pass a solderability verification prior to use or storage. If components cannot be purchased pretinned, they are sent to a contractor for tinning, and must pass solderability verification prior to use or storage. Other parts – process sensitive parts – may be stored without a verification of solderability with the approval of the DPRO and the Naval Warfare Assessment Division.

The solderability maintenance plan has led to a reduction in solderability related defects and increased reliability of soldered connections. The plan can also help identify exceptionally good or poor component suppliers. Overall, it prevents non-solderable components from reaching stock or the manufacturing floor.

Statistical Process Control

LM-GES lacked an aggressive formal procedure for process control prior to 1990. Data was reactive and not real time; understanding of process control was limited; and dedicated resources for process control were non-existent.

LM-GES initiated an aggressive SPC program, and a proactive attribute and variable data collection program was established with collection occurring early in the production process. Manufacturing reviews were eliminated, and formal SPC training was given to all personnel. Resources were dedicated for process control, and SPC procedures were also developed and implemented. A flowchart (Figure 3-5) was developed to ensure consistent implementation of SPC, providing guidance in SPC tool selection. All SPC procedures are now reviewed and updated regularly.

Since implementing SPC, LM-GES has reached a manufacturing quality level of 5.2 sigma. Process consistency is the norm with immediate feedback on process effectiveness. Operator ownership has become strong, and quality is built into products through control of processes.

Supplier Report Cards

LM-GES uses a Supplier Feedback Report (Figure 3-6) to provide its supplier base an integrated, comprehensive rating that covers all factors of Lockheed Martin requirements including quality, responsiveness, delivery, and Certified Supplier Program readiness. This information is needed to provide tangible data for the supplier selection process.

The Supplier Feedback Reports are distributed to suppliers every quarter. Each Feedback Report uses a color format for suppliers to quickly see its quality, delivery, and total scores. Suppliers can determine how they stack up in performance with the 11 LM-GES business units that comprise the database. Monthly plots in the three rating categories show the supplier's trends for the past year's activity. The total point score given to a supplier affects its retention as a supplier.

Since 1992, use of the Supplier Feedback Report and the Certified Supplier Program have improved purchase order cycle time by 71%, reduced the number of suppliers from 3,650 to 580, and decreased discrepant invoices by 97% (Table 3-2).

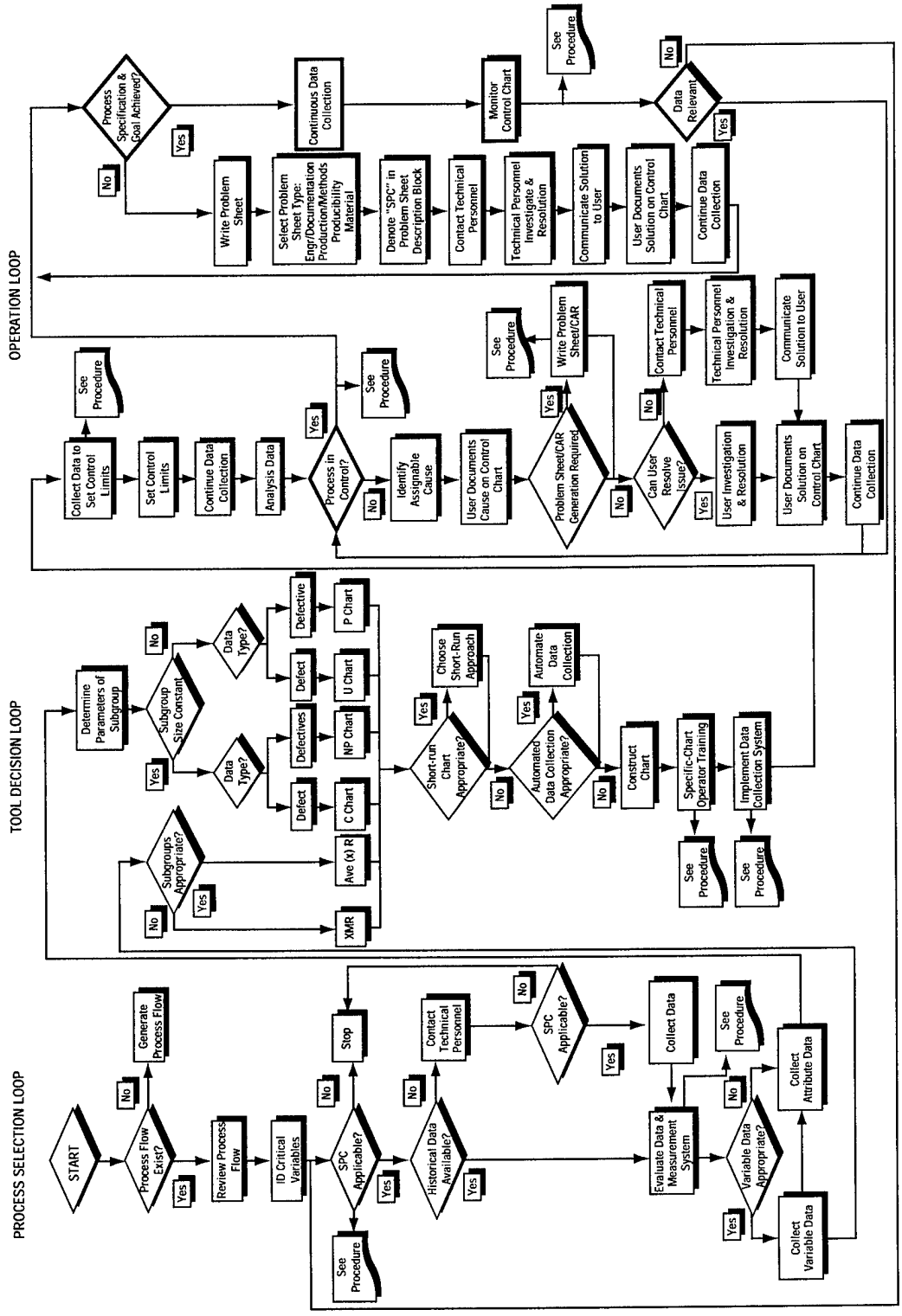


Figure 3-5. SPC Flow

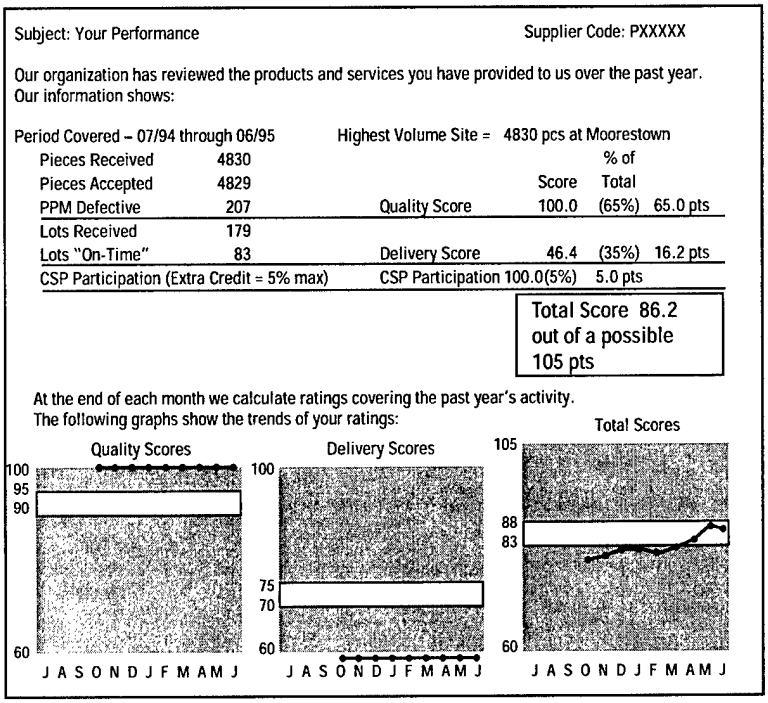


Figure 3-6. Sample Supplier Feedback Report

Table 3-2. Results of Supplier Feedback Report and Certified Supplier Program

	1992	9/95	%
PO Cycle time • Growth in GPA's	45 days	13 days	71%
Supplier Reduction • Fix or Delete matrix	3,650	580	84%
On-time Delivery Performance • Supplier report cards	44%	78%	77%
CSP Suppliers • Supplier Symposiums	12(93)	148	1233%
PMI Cycle Time • CSP Program	40 days	5 days	88%
Problem Sheet Cycle Time • Metric generation/ownership	43 days	13 days	70%
MR Backlog • GPA's, Supplier Reduction	7975	1530	81%
MR's>60 days • System Upgrades	3400	63	98%
Discrepant Invoices	1003	28	97%

Logistics/Management

AEGIS Excellence Award Program

LM-GES manages the AEGIS Excellence Award Program that recognizes outstanding contributions and publicizes superior performance throughout the AEGIS community. Initiated in 1971 by the NAVSEA AEGIS Project Manager to challenge participants to excel, the program was limited to Navy and prime contractor personnel working on AEGIS weapon system development.

Employees at participating agencies and suppliers are now included and motivated to improve. The program consists of individual and team awards, contractor awards, and support publications. Individual and team awards are presented at quarterly awards ceremonies, and include a framed parchment citation and token monetary award. Contractor awards are selected by the AEGIS Program Manager. Recipients may be Navy units, facilities, or contractors. The vice president of LM-GES may also select suppliers to receive the award. These facilities are presented with the AEGIS excellence flag. Some facilities have been recognized by the President of the United States and U.S. Senators after receiving the awards. All recipients are recognized through a quarterly AEGIS excellence newsletter which also serves as a communication vehicle for the entire AEGIS Government/Industry team. The Admiral in charge of the AEGIS program presents this prestigious award to the individuals/teams being recognized. The AEGIS Excellence Program is in its 25th year and is viewed by many as "one of the best" motivational programs.

AEGIS Naval Systems Metrics Program

LM-GES established the AEGIS baseline metrics program in 1991 to develop a set of computer program metrics for each baseline product and to assess the quality, reliability, maintainability and producibility concepts involved with computer program development, maintenance, and upgrade.

The metrics program focuses on key project management and quality characteristics, and supports the requirements of the AEGIS transition to DOD-STD-2168 and TQM. A metrics plan was developed and approved by the customer (PMS 400) and identifies two major metrics sets – Project Management and Quality. The Project Management metrics include computer program size, requirements volatility, test progress, and project personnel tracking. The Quality metrics are design/code review corrective action items, errors/defects, reliability/maintainability/availability, and code complexity.

LM-GES applied an engineering process to produce the metrics set. AEGIS collected 1400 measurements prior to

this effort in the global AEGIS metrics set, and a Process Improvement Committee evaluated the 1400 measures and made a determination of which metrics should be included in the initial metrics set. The measurements were filtered by using a series of criteria which were in compliance with DOD-STD-2168/TQM, IEEE quality requirements, the Software Engineering Institute Level 3 metrics, LM-GES process improvement criteria, and AEGIS criteria. The initial AEGIS metrics set was determined, and of the 1400 measures that were taken in the global set, 24 measurements remained in the initial set.

The initial metrics set is used for each baseline product and tailored for its requirements. A metrics plan is developed for the baseline product and reviewed by the Metrics Analysis Group. From the analysis, this group generates Computer Product Improvement recommendations, and the metrics plan is reviewed by management for implementation. Currently, LM-GES has about 80% of the metrics automated. Present work is focusing on automating all metrics collection on a SUN workstation.

The AEGIS metrics analysis has been instrumental in the redesign of AEGIS tactical computer programs and support programs. The metrics program has provided Computer Product Improvement for computer programs, increased management control/oversight, developed specific improvement recommendations in both product and process, and increased quality and productivity.

Communications Process

As LM-GES faced a dramatically different and rapidly contracting market, it determined that its methods of communications would not meet the needs of the personnel to support the new organization. In 1991, the LM-GES communications process was essentially non-existent. An employee survey taken in 1992 revealed that over two-thirds of the employees used the traditional "grapevine" as their primary source of information about the company.

Since that time, LM-GES has developed an integrated communications process encompassing printed, verbal, and electronic elements. *UpFront* is the GES weekly newsletter published every Tuesday at the Moorestown site with copies FAXed to other worldwide LM-GES sites. Staff meetings, key communications meetings, skip-level meetings, work center standup meetings, and town meetings called by the teams comprise the verbal communication effort. The "48 hour flowdown" is the primary vehicle for disseminating information from the Monday staff meeting held by the senior executives. The information is passed through two levels of management directly to individual team members by the close of business on Wednesday. A 20-station Employee News Network is a closed circuit video network that allows instant updates of critical information to employees throughout the plant.

An employee survey conducted in September 1994 reveals that the improvements in the communication process are producing positive results – 80% felt their managers are credible, 77% rated the effectiveness of communication at "5" or better (10 is best) and the dependence on the grapevine as the primary source of information had dropped from 67% to 20%. LM-GES continually improves its communications process and is currently analyzing data from the September 1995 employee survey.

Community Leadership

In support of its community support effort, LM-GES has developed an effective process which identifies and directs support to areas of need in the community.

LM-GES is active in the local United Way, including membership on the board of directors. Over 80% of LM-GES employees contribute to United Way, making LM-GES the single largest contributor to the local campaign. In addition, LM-GES provides excess computer equipment to United Way for distribution to United Way agencies and other community organizations. Employees also provide tutoring support to Morgan Village Middle School, participate in a Partnership with the Moorestown School system, donate numerous hours of volunteer assistance to community organizations helping the needy, and actively participate in the Chamber of Commerce of Southern New Jersey. LM-GES employees responded to the 1995 Bond Drive with over 96% participation and collected over 10,000 cans of food for a local Scouting food bank.

LM-GES understands that community leadership is important and is currently developing an employee recognition process tied to individual support of community projects.

Cost/Schedule Control System Criteria Storyboard

LM-GES uses a storyboard as a training tool and for reference during Government Cost/Schedule Control System Criteria (C/SCSC) reviews to provide a clear understanding of the C/SCSC system. Previously, the government review team read over 200 pages of LM-GES's C/SCSC system description. C/SCSC specialists would then provide classroom training using generic data which was not contract-specific. This data was displayed using overhead projectors, and the full display of how the data was integrated could not be captured. Many LM-GES Cost Account Managers were evaluated as deficient in terms of C/SCSC knowledge, and there were a significant number of discrepancy reports. A more effective means of communication was needed.

LM-GES now uses a storyboard which consists of a single trace cost account, a collection of data for the account, and organizing and displaying the selected data in a storyboard format with emphasis placed on demonstrating how the system is integrated and traceable. This information is posted on the walls where the review team is located and is available for reference. A presentation of the storyboard is conducted by the Cost Account Manager or the Program Manager.

Using the storyboard provides several benefits. The government team has a clear understanding of the C/SCSC system, resulting in fewer discrepancy reports. Cost Account Managers study the storyboard prior to the reviews. In February 1995, 40 Cost Account Managers were interviewed, and all successfully passed the review. The storyboard saves the government work during the review by providing over 60% of the required data traces. Since implementation of the storyboard, LM-GES closed all deficiency reports before the review exit briefing.

Customer Satisfaction Improvement Program

LM-GES had to develop a simple, effective customer satisfaction improvement process in 1994 in response to several customer satisfaction issues. The issues included two primary customers receiving systems containing approximately 736 line items (22 trucks of equipment). There were multiple lines of communication from the customer to the various areas of company expertise on some problem issues, while others went unresolved as customers did not know who the designated LM-GES point of contact was. At times, problem resolution took too long to meet customer needs and lessons learned were not being shared. Consequently, LM-GES developed a simple but effective improvement process.

A single point-of-contact was established to coordinate all customer feedback, a database was developed to standardize the information reporting; and a customer satisfaction index form was introduced. Also, an aggressive goal of problem closure within one week was instituted with regular quality/management meetings on any open issues.

The customer satisfaction index had six primary areas for customer rating – communications, documentation, corrective action, equipment receipt, equipment installation, and equipment test support. To rate the particular categories, the customer grades the area green, yellow, or red. Green indicates isolated or no issues. Yellow indicates repetitive issues with impact to customer schedule and red, a safety hazard or severe impact to schedule and overall system performance.

Several benefits have been recognized from this customer satisfaction process. It allows tracking, documentation, and trend analysis of quality assurance concerns. The single line of reporting not only improves communication efficiency, it also builds an effective working relationship with the customer.

Document Control

LM-GES developed a central document control system for the Operations Department in 1989. The previous system had many problems. There were multiple document repositories with minimal control on issuance and recall of documents. There was no automatic recall of obsolete documents, and they were often found in work centers. The paper filing system was difficult to maintain and did not include and record document owners.

LM-GES established one central control room for all drawings, parts lists and process master documents. The issuance update and recall for all documents is now controlled by a computer program developed for this task. The computer program collects and monitors document records on a daily basis. The system was established with controls to screen requesters and penalize work centers with past due returns. All controlled documents are printed on yellow paper with bar coding and control stamps for easy identification.

Lockheed Martin GES' document control system has quickly and accurately eliminated problems associated with the previous method.

Electronic Delivery of Products

As the result of a Basic Ordering Agreement, LM-GES now delivers ORDALTs to the Navy in electronic format. Previously, the delivery of paper copies was a labor-intensive and resource-consuming activity. Just the Preliminary Allowance List portion of the ORDALT could consist of 100 to 200 pages, and 25 copies of the complete ORDALT were required.

Deliveries are Standard Graphic Markup Language compatible and CALS compliant. The complete ORDALT (including all enclosures other than "B" size or larger drawings) is delivered digitally, allowing simultaneous availability to all cognizant personnel.

Electronic delivery has resulted in the Basic Ordering Agreement requiring earlier delivery (90 days prior to proof-in kit delivery instead of 45 days) of the preliminary ORDALT to the Navy. Additionally, the review of the final ORDALT by LM-GES has been reduced from 180 days to 90 days. Delivery of the final ORDALT following proof-in has been reduced from over 360 days to 180 days.

Electronic delivery has resulted in substantial savings in reproduction costs, reduced review/revision cycle times, and complies with DOD directives for digital delivery of products.

Employee Suggestion Program

LM-GES has had a formal Employee Suggestion program since 1991 for submitting ideas to improve products, safety, operations, sales, or quality. These suggestions are accepted from all personnel and may be submitted by individuals or teams. The previous suggestion program had no controls, with an average suggestion age of 200 days. There was a long backlog of suggestions awaiting review, and employee confidence and participation in the program was low. Analysis was not being conducted to assess the impact of suggestions on business.

The program was revitalized by implementing sweeping improvements. A suggestion tracking system database was created detailing suggestion age and responsibility assignments. This information comprises weekly reports to responsible managers. A review board has been instituted to validate and facilitate the tracking process. Accurate cost analysis was initiated, and a process was developed to evaluate intangible savings. Suggestions are currently investigated and evaluated by responsible individuals in their areas of expertise. Evaluations and awards are reviewed by a board of members from all parts of the company; when suggestions are approved and successfully implemented, cash awards are made. Tangible awards are 15% of the estimated labor and material savings. Intangible awards are up to $500 and are based on cycle time, ergonomics, facilities, ESH, material, and labor utilization.

Work center incentive pools were created in 1994 to encourage participation by design teams. This feature of the program fosters multi-functional teamwork by allowing all members of a work center and associated design teams (including support personnel) to share in the accumulated benefits of successful suggestions implemented during the year. It provides a forum for the publication of design team projects and ideas, and offers an incentive for cooperation within and outside the work center.

ESD Control Program

LM-GES has established a comprehensive ESD control program that meets the requirements of MIL-STD-1686. Prior to 1991, LM-GES used an ESD philosophy that required it to identify parts and assemblies that were ESD sensitive up to 2,000 V only.

The move to MIL-STD-1686 compliance has simplified several aspects of the ESD program. For example, it eliminates the question of what is ESD sensitive since all components are handled as if they were ESD sensitive. In addition, it reduces the controls required as well as the chance of mishandling sensitive components. The LM-GES plan includes all aspects of ESD controls including workstation certification, personnel equipment and certification, assembly storage and movement, and items such as calibration and training. ESD issues are also part of the design matrix. In addition, the program includes other special features such as an ESD council which maintains and updates ESD program requirements, investigates ESD concerns and develops corrective actions. An ESD Mentor Program was established that assigns an ESD expert to each work area.

By implementing this comprehensive plan, several benefits have been realized. There is an overall improved awareness of ESD concerns and issues. ESD safe practices have become commonplace throughout the plant. And since the incorporation of the program in 1991, AEGIS digital modules have exhibited fewer failures per year (Figure 3-7).

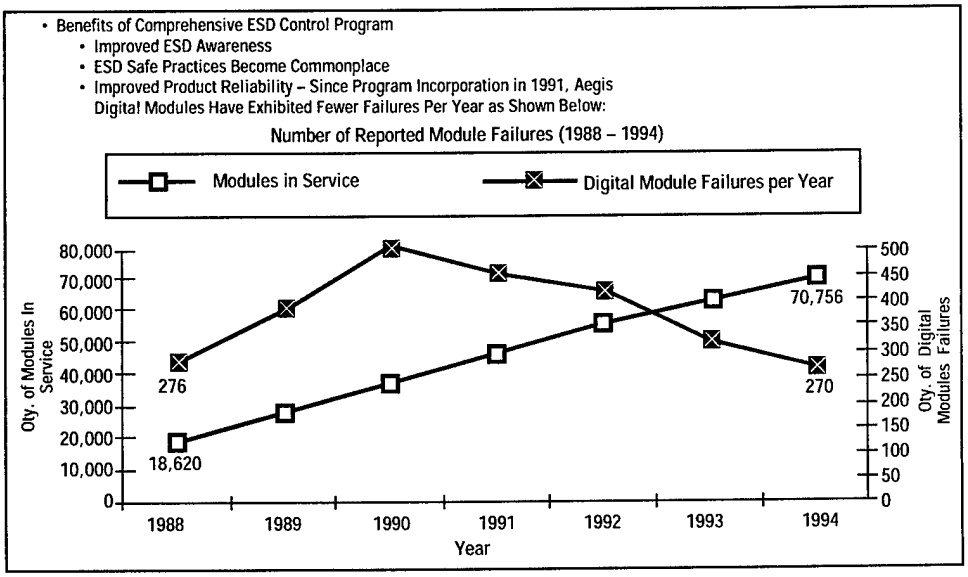


Figure 3-7. Number of Reported Module Failures (1988-1994)

Field Modification Bulletins

The Field Modification Bulletin (FMB) at LM-GES is an expedient and timely means to implement production-related issues on fleet equipment, while ensuring equipment configuration and logistics integrity. This practice quickly disseminates the information on performing minor modifications to LM-GES cognizant fleet systems. procurement system also allows for the collection of necessary data that interfaces with a centralized equipment database. This database contains information such as the custodian name and code, property serial number and tag number, acquisition date, contract, and cost, and location of equipment. It is accessible to custodians. Equipment custodians must access the database as part of performing quarterly self audits of their equipment and training. The audit consists of a series of questions pertaining to training, knowledge of written procedures, and other issues of equipment and document control.

This system provides management with a mechanism to foster individual ownership and responsibility for equipment without maintaining a large, centralized staff for tracking equipment. Also, a centralized database is maintained and accessible to those who need information on equipment status and location.

Government/Contractor Communications Meetings

LM-GES established twice-monthly communications meetings in 1990 to promote effective working relationships. The two-hour meetings are attended by the Defense Contract Auditing Agency, DPRO, and LM-GES personnel. These meetings address current and outstanding issues listed in the published agenda. Face-to-face discussions clarify and facilitate requests for information and expedite the closure of outstanding issues. Critical matters such as material management, forward pricing rates, interim/final billing rates, cost savings initiatives, and allowable costs are resolved in a timely manner. The meetings also foster open communications that build trust and teamwork, resulting in increased efficiency and better utilization of resources.

Government Property Management

LM-GES has developed procedures to protect and manage over 10,000 pieces of Government equipment valued in the hundreds of millions of dollars. The procedures developed empower individual employees to be custodians of equipment under their care.

When equipment needs to be procured, a Contract Appropriation Request form is completed specifying the equipment required. Once the request is approved, a Material Request is issued and the equipment is purchased. Using this procedure, each piece of Government equipment (as well as corporate equipment) is assigned to the individual within the organization that requested the equipment. This results in a custodian-based, decentralized system. This procurement system also allows for the collection of necessary data that interfaces with a centralized equipment database. This database contains information such as the custodian name and code, property serial number and tag number, acquisition date, contract, and cost, and location of equipment. It is accessible to custodians. Equipment custodians must access the database as part of performing quarterly self audits of their equipment and training. The audit consists of a series of questions pertaining to training, knowledge of written procedures, and other issues of equipment and document control.

This system provides management with a mechanism to foster individual ownership and responsibility for equipment without maintaining a large, centralized staff for tracking equipment. Also, a centralized database is maintained and accessible to those who need information on equipment status and location.

Malcolm Baldrige-Based Quality Plan/ Process

LM-GES was involved in several quality assessment initiatives in 1994. It was awarded the Malcolm Baldrige-based New Jersey Quality Achievement Award, was selected by *Industry Week* as one of the 10 Best Plants in America, and has achieved ISO 9001 registration. After winning the New Jersey Quality Achievement Award, the LM-GES top management challenged its team to determine what the company needed to gain the 1000 points.

The answer was MB 1000, an approach to review, analyze, and categorize the business process findings from all evaluations in 1994. The Malcolm Baldrige criteria has been applied to help develop business improvement action plans, and a senior staff member assigned as the Champion for each of the MB 1000 Improvement Initiative. The MB 1000 Team has identified 11 key business process improvement opportunities, and an implementation proposal has been developed for each opportunity.

LM-GES has assigned multifunctional teams to address each of the 11 improvement opportunities in concert with its overall TQM Philosophy.

Organizational Development and Training

As the company proceeded with Vision 2001 (its strategic plan for the future), it became apparent that training needs for the new organization were not being met. The company had no central source for training or development

– technical training was the responsibility of the Quality department. The operations department maintained its own training group and with the buyout by Martin Marietta, LM-GES lost the training resources available from General Electric. LM-GES realized that it needed to establish a long-range human resources plan to support Vision 2001 and accommodate rapidly-changing technology.

The new process has transferred all training responsibilities to the Human Resources department using six fulltime professionals. LM-GES has performed needs assessments of the organization, departments/ functions, and individuals utilizing several tools and methods, including Dale Carnegie and the Center for Creative Leadership. The process reaches all levels including management, professional, technical and on-the-job training. Management training is tailored to various levels from entry-level through senior management staff. Skills are assessed at each level, and tailored training is provided to those managers who are considered promotable. Technical skills are developed using traditional methods – contracted training, tuition refund programs through local universities, and on-site continuing education such as a program with the local county college.

The LM-GES on-the-job training was a direct outgrowth of the GES Competitive Initiative with revisions in the government contract specifications that broadened the method of delivery of required training programs. Fifty-two volunteer lead operators were trained to be trainers; cross-training matrices were developed for each work center; and grants were received from the state of New Jersey to fund a significant portion of the training.

LM-GES is currently investing an average of $1K per employee per year on development and training. Although the process has been in place only 15 months, LM-GES has seen positive results. There are low turnover rates, leadership continuity, workforce versatility, and reduced cycle times in the shops. Employee idle time has dropped to zero, scrap has been reduced from 1.4% in 1993 to the current 0.4%, and defects have been reduced from 157.1 defects per million to 102.3 defects per million.

Outsourcing Product Transitions

Subassemblies of the AEGIS system were manufactured at the Moorestown site during the early 1990s when LM-GES was General Electric. General Electric manufacturing philosophy was changing at that time to one that required outsourcing of all but core processes. In addition, defense budgets were reduced faster than the costs of many subassemblies made by the Moorestown site. These two factors required a major change in the company's manufacturing strategy.

The first restructuring began in 1990 with a transfer of four major subassemblies to a high-technology GE facility (REC-South) and outsourcing of six additional subassemblies. To ensure a smooth transition that would not delay AEGIS system deliveries, LM-GES instituted a detailed process for developing new sources. The company started with mature products with stable build-to-print data packages. A dedicated, permanent, multifunctional Sourcing Team was formed to develop new suppliers. The team was responsible for developing and implementing the overall transition plan, assessing and selecting the best suppliers, ensuring/providing on-site technical assistance/support to the supplier, ensuring successful pilot runs, performing production readiness reviews, and reporting program progress status to both GE and Navy officials. LM-GES resurrected the process again in 1993 when it outsourced additional subassemblies.

Lessons learned during the process implementation include the need for detailed initial planning that involve the customer; using a detailed process that can lead to consistency and credibility with potential suppliers and the customer; easily available on-site support is required; over communication reduces the rumor mill; and all process documentation must be certified before providing it to the suppliers.

Benefits of this highly structured process include a substantial reduction in cost of the subassemblies with a continuation of high quality and on-time system deliveries. LM-GES surprisingly found the AEGIS program was receiving widespread support from Congressional delegations since many of their suppliers were outside the state of New Jersey.

Process Certification

LM-GES instituted Process Certification to certify and freeze an existing process. Previously, processes were changed with no formal review resulting in numerous difficulties. For example, changes were made without regard to their impact on engineering, processes were changed several times resulting in multiple processes that could be used, and changes were made solely to take advantage of particular operator skill or preference. Lack of accepted formal processes led to additional problems. Processes would not necessarily be followed, or operators followed their own.

Under Process Certification, a specific operation is followed. A process flow is first constructed and a flow down tree – a list of all processes and documents applicable to the process – is established. A cross-functional team reviews the process for compliance to the contract Environmental Health and Safety and producibility requirements. The process is also reviewed for cost and technical rationale. When approved by the board, the process is entered into a database of frozen, approved processes. From this point,

any changes to the process must be approved by the process review board. Once most processes are established and frozen, the process review board primarily handles process change requests.

Advantages have already been realized – processes are efficient and effective, and product quality is controlled more effectively. Since this process certification plan was put into effect, scrap has been reduced by 78% and defects have been reduced by 84%.

Processing Government Furnished Property

To ensure the most cost effective performance of contract tasking and provide optimum service to its customer, LM-GES gave its configuration management operation the task of managing the extensive Government Furnished Property (GFP) program.

The challenge to the GFP team was to minimize the amount of GFP required for the numerous tasks, minimize the processing cycle time, and maximize the use of GFP in the possession of LM-GES within contractual guidelines. LM-GES organized four teams of more than 50 individuals from 10 different departments to participate in analyzing the existing property management process. These teams made improvement recommendations in 100 areas of property flow. These areas included eliminating redundant inspection, packing and movement efforts; identifying incomplete, conflicting and inadequate documentation; timing improvements for identifying quality deficiencies; and properly managing priority conflicts between development and production resources.

The configuration management organization established one central point of control for managing all GFP. This resulted in minimum handling and movement of equipment, early identification of incoming hardware deficiencies (within warranty), efficient use of user site staging space, and timely equipment installation scheduling. These actions resulted in lower overall costs and an improved process flow.

Process-Oriented Contract Administration Services Teaming

Over the 25 years of the AEGIS program, LM-GES has teamed with the DPRO to address program-related issues. This teaming approach was formalized in August 1994 by the Commander of DPRO Delaware Valley and the President of LM-GES in a Process-Oriented Contract Administration Services (PROCAS) Teaming Agreement. The intent of PROCAS was to create and encourage a cooperative spirit within these organizations to improve quality and lower costs on a continual basis. It provides for customer support by forming teams to evaluate, measure, control, and improve critical business processes. LM-GES and DPRO established teams to identify processes for improvement opportunities selected using SPC techniques. Identified issues/processes were to be monitored, studied, and simplified for improvement.

One mission was to establish a PROCAS team to continuously improve performance in delivering technical manuals (CDRLs) in accordance with Contract Delivery Schedules. Before implementing the system, there were three distinctive delivery processes which included 23 steps and a 33-day average cycle time. The team reviewed the requirements and documented the process flow including DPRO responsibilities. The team determined that procedures required updating. In addition, teaming provided LM-GES with feedback to ensure contract requirements were met.

The results of teaming include increased user satisfaction by reducing distribution of technical manuals. The delivery process was reduced from 23 to 8 steps. The average cycle time was reduced 90% from 33 days to 3 days. Over 130 manuals were successfully delivered through the teaming process. PROCAS teams continue to strive in providing benefits to the customer as well as to LM-GES.

Readiness Based Sparing Modeling

Since 1970, LM-GES has provisioned the AEGIS weapon system with onboard spares selected by the SEASCAPE Readiness Based Sparing (RBS) model. RBS provides the proper mix of spares with a system to achieve a prescribed level of operational availability. Items selected by SEASCAPE ensure that the operational availability (readiness) target will be accomplished at the lowest possible cost, and that configuration integrity of the system is maintained.

The SEASCAPE RBS software was developed by LM-GES personnel and is owned by the U.S. Government. SEASCAPE economically and automatically selects spare items by criteria applied for performance effectiveness. Specifically, it determines the additional availability contribution provided by adding incremental spares for each part number. Starting with no spares, each time the contribution of one more spare is determined to be greater than a prescribed minimum requirement, SEASCAPE will provide that spare. SEASCAPE accounts for fault tolerance and will indicate that with all things equal, the availability provided by a given number of spares will be higher for a less critical part than for a more critical part. Therefore, SEASCAPE will provide fewer spares to support fault tolerant equipment, with a result that the availability goal is still achieved but at the lowest possible cost.

Between 1992 and 1995, application of the SEASCAPE model – together with a more accurate assessment of the fault tolerance within the AEGIS weapon system – has

resulted in savings in spares cost for each of the DDG-51 AEGIS destroyers. This cost reduction was realized with no reduction in availability.

Supplier Symposiums

In 1991, LM-GES began conducting supplier symposiums to foster team building among suppliers and facilitate upfront, two-way communication. Before these supplier symposiums, drawings, specifications, and statements of work were sent to suppliers to hopefully receive quality parts on schedule, and there was no communication of LM-GES's business plans.

Supplier symposiums are held off-site in Moorestown, New Jersey area at least once a year. Approximately 100 suppliers are invited to the plant to listen to LM-GES' business and customer strategic plans and learn about their role in the execution of objectives. Often representatives from the NAVSEA Program Office participate by providing news of future Navy objectives. Benefits of the open communication allow suppliers to make sound management decisions resulting in cost reductions in a downturning defense environment. Suppliers also share concurrent engineering ideas, and team building is strengthened.

Technical Information Services

LM-GES' Technical Information Services is an extensive, electronic-based information center that features online library catalog access to the books, serials, conference proceedings, and audio and videotapes held by the three Lockheed Martin sites.

The Technical Information Service represents a commitment by management to provide funds, staff, and space required for technical employees who research current and archived topics in radar, military developments, mathematics, manufacturing methods, and science. The Center incorporated electronic-based features in 1992 to replace the manually-based card file system, searches, and microfilms. The Center now includes an electronic based on-line card catalog system, the DIALOG search system, and access to military and industry specifications and standards using Information Handling Services CD-ROMs. The on-line card catalog system provides LM-GES users with electronic card catalog access to three LM-GES libraries from desktops. It supports keyword research and is available seven days a week, 24 hours per day. The DIALOG system provides research into 230 electronic databases, and users are assisted by the Center's staff. Information handling services include subscription to all military, industry, and vendor data on CD-ROM. The Center is equipped with study space, VCRs, CD-ROM workstations, and access to experts via Teltech.

Future plans include adding other Lockheed Martin sites to the on-line library catalog system in 1996. The Center's improved efficiency and additional services have rewarded LM-GES with a well-informed technical employee base.

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
ADO	AEGIS Depot Operation
ASMAL	Automated Surface Mount Assembly Line
ATE	Automatic Test Equipment
ATIC	AEGIS Tools Implementation Committee
BMP	Best Manufacturing Practices
CALS	Continuous Acquisition and Life-Cycle Support
CM	Configuration Management
C/SCSC	Cost/Schedule Control System Criteria
CSEDS	Combat System Engineering Development Site
CSI	Customer Satisfaction Index
CVP	Characteristic Verification Program
DFT	Design for Test
DMS	Diminishing Manufacturing Sources
DOD	Department of Defense
DPRO	Defense Plant Representative Office
ECP	Engineering Change Proposal
EPI	Engineering Process Improvement
FMB	Field Modification Bulletin
FMS	Foreign Military Sales
FRB	Failure Review Board
GPA	Group Purchase Agreement
GFP	Government Furnished Property
ICAPS	Interactive Computer Aided Provisioning System
IPD	Integrated Product Development
IPT	Integrated Process Team
IUE	International Union of Electronic, Electrical, Salaried Machine and Furniture Workers
JTAG	Joint Test Action Group
LM-GES	Lockheed Martin Government Electronic Systems
LRU	Line Replaceable Unit
MRB	Material Review Board
NSCC	Naval Systems Computer Center
ORDALT	Ordnance Alteration

PDT	Product Development Team
PIC	Product Improvement Committee
PIOS	Production and Inventory Optimization System
PR	Preliminary Review
PROCAS	Process-Oriented Contract Administration Services
PTC	Production Test Center
PTD	Provisioning Technical Documentation
RBS	Readiness Based Sparing
SDB	Small Disadvantaged Business
SCIN	Site Change Implementation Notice
SCRIBE	Specification Change, Review, Implementation Baseline and Evaluation Board
SPIG	Software Center Process Improvement Group
STARSYS	Status Tracking and Reporting System
SQA	Software Quality Assurance
TEG	Technical Evaluation Group
WISDOM	Wirewrap Integrated System Design Optimizing Maintenance

Appendix B

BMP Survey Team

TEAM MEMBER	ACTIVITY	FUNCTION
Larry Robertson (812) 854-5336	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Chairman**
Amy Scanlan (301) 403-8100	**BMPCOE** College Park, MD	**Technical Writer**
Adrienne Gould (703) 696-8485	**Office of Naval Research** Washington, DC	**Technical Writer**
	DESIGN/TEST TEAM #1	
Ron Cox (812) 854-5251	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Leader**
Steve Ratz (317) 306-7151	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	
Mike Dobra (909) 273-4618	**Naval Warfare Assessment Division** Corona, CA	
	DESIGN/TEST TEAM #2	
Larry O'Connell (505) 844-1061	**Sandia National Laboratories** Albuquerque, NM	**Team Leader**
Mary Behnke (317) 306-7293	**Naval Air Warfare Center** **Aircraft Division - Indianapolis** Indianapolis, IN	
Vartan Khosharian (619) 553-3371	**NCCOSC** San Diego, CA	
	PRODUCTION/FACILITIES TEAM #1	
Nick Keller (812) 854-5331	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Leader**
Randy Kuehn (812) 854-4669	**Crane Division** **Naval Surface Warfare Center** Crane, IN	
Art Boysen (360) 396-2191	**Naval Undersea Warfare Center** **Keyport Division** Keyport, WA	

PRODUCTION/FACILITIES TEAM #2

Rick James (317) 226-5619	**Electronics Manufacturing Productivity Facility** Indianapolis, IN	**Team Leader**
Ken Reid (317) 226-5622	**Electronics Manufacturing Productivity Facility** Indianapolis, IN	
Dale Padgett (812) 854-6268	**Crane Division** **Naval Surface Warfare Center** Crane, IN	

MANAGEMENT/LOGISTICS TEAM #1

Larry Halbig (317) 306-3838	**Naval Air Warfare Center Aircraft Division - Indianapolis** Indianapolis, IN	**Team Leader**
Ted Brindle (317) 306-7508	**Naval Air Warfare Center Aircraft Division - Indianapolis** Indianapolis, IN	
David Platteter (317) 306-4903	**Naval Air Warfare Center Aircraft Division - Indianapolis** Indianapolis, IN	

MANAGEMENT/LOGISTICS TEAM #2

Rick Purcell (301) 403-8100	**BMPCOE** College Park, MD	**Team Leader**
Greg Tabata (909) 273-4969	**Naval Warfare Assessment Division** Corona, CA	
Gerry Thomas (812) 854-1797	**Crane Division** **Naval Surface Warfare Center** Crane, IN	

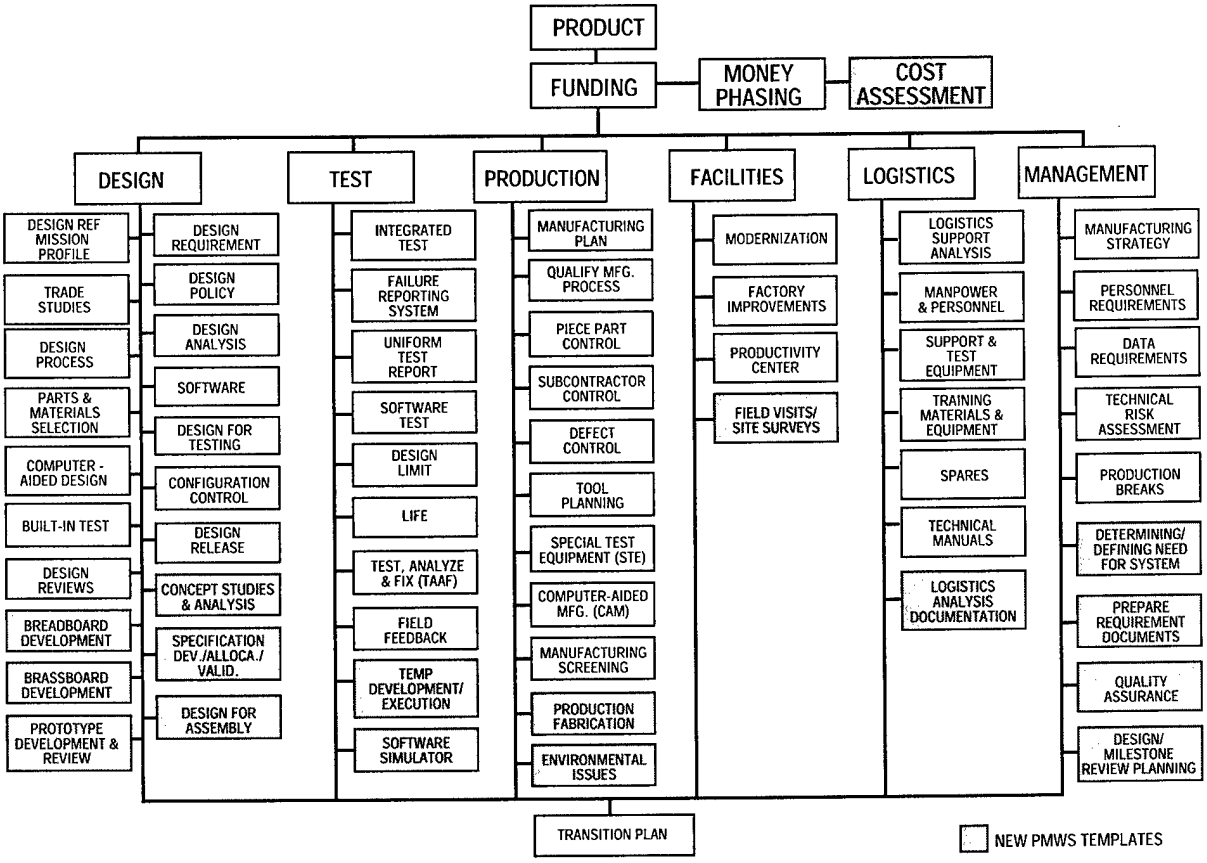
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"

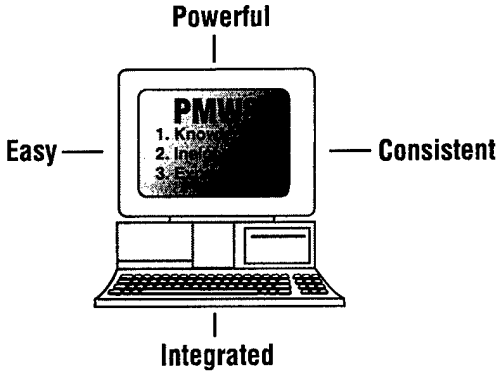


Appendix D

BMPnet and the Program Manager's Workstation

The Program Manager's Workstation (**PMWS**) is a series of interrelated software environments and knowledge-based packages that provides timely acquisition and engineering information to the user. This Workstation is hosted on the BMPnet that supports communication nationwide to promote technology transfer and continuous improvement. Access to BMPnet is through modem dial-in, free PMWS software, Internet, World Wide Web, or CD-ROM. Besides PMWS, BMPnet features include communication by electronic mail and file transfer; access to Special Interest Groups on more than 75 topics including producibility and Government specifications; information upload and download capability; and the ability to download BMPnet-resident programs.

PMWS includes **KnowHow**, an electronic library of expert technical assistance, including an intelligent search capability that gets the information users need on the screen in less than three minutes; the Technical Risk Identification and Mitigation System (**TRIMS**), a technical risk management system that may be tailored to the user's needs; the BMP database that contains over 2,000 abstracts on documented best practices; and SpecRite, a performance specification development tool.



PROGRAM MANAGER'S WORKSTATION

KnowHow is . . . Knowledge through an automated and intelligent information access system that speeds the search for required information by up to 95%. Typically, the information needed is on the screen in less than three minutes.

KnowHow features include:

- Personalized acquisition planning guidance, both high and low level, as appropriate.
- Information required for user's specific job.
- Special, logic-driven menu that allows fast access to cut research time by up to 95%.
- On-line user's manual and help.
- Application as a learning tool for new acquisition personnel.

TRIMS brings . . . Insight which identifies and ranks those program areas with the highest risk levels.

TRIMS features include:

- Ability to conduct continuous risk assessments to take preemptive corrective action.
- Tracking capability for key project documentation from concept through production.
- Identification function of goals, personnel, and future activities in development processes.
- Default values for many categories by program type.
- Ability to tailor all fields to suit individual program requirements.
- Reports generation.

The **BMP Database** provides . . . Information that comes directly from verified practices in industry that government experts search out looking at the best to collect answers and solutions.

BMP Database features include:

- Information on best practices in manufacturing, design, test, facilities, production, management, and logistics from 80 companies or activities.
- Ability to search for information using a natural language interface.
- Capability to print information to a file, disk or directly to a local printer.
- Phone numbers of points of contact in companies who have been surveyed.

SpecRite can help . . . Develop a performance specification generator based on expert knowledge across the services to guide acquisition personnel in creating specifications for their requirements.

SpecRite features include:

- DOS-base (runs on any PC).
- Organization and structure for the build/ approval process.
- Knowledge-based guidance and assistance.
- Flexible, modular structure.
- Output in MIL-STD 961 format and in WordPerfect 5.1 files.

To access BMPnet, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulation set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems or (703) 538-7267 for 9600 baud and 14.4kb. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the download of the special modem program. Then call back using this program and access all BMPnet functions. The general user account is:

USER PROFILE: BMPNET

USER ID: BMP

Password: BMPNET

If you want a personal account to receive e-mail, forward your request to Ernie Renner (BMP Program Manager) or Brian Willoughby (BMPnet Program Manager at CSC). If you encounter problems, please call (301) 403-8179.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently six Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The six BMP satellite centers include:

Corona, CA

Chris Matzke
Quality Assurance Engineer
Naval Warfare Assessment Division
Code QA-21, P. O. Box 5000
1456 Mariposa Drive
Corona, CA 91718
(909) 273-4992
fax: (909) 273-5315
internet: cmatzke@bmpcoe.org

Louisville, KY

Marshall Bramble
BMP Representative
Louisville Site, Crane Division
Naval Surface Warfare Center
5401 Southside Drive
Louisville, KY 40214
(502) 364-5272
fax: (502) 364-5272
internet: mbramble@bmpcoe.org

Oak Ridge, TN

Tammy Graham
BMP Representative
Martin Marietta Energy Systems
P. O. Box 2009, Bldg. 9737
MS 8091
Oak Ridge, TN
(615) 576-5532
fax: (615) 574-2000
internet: tgraham@bmpcoe.org

Rockford, IL

Dean Zaumseil
Mid-Western Representative
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5530
fax: (815) 654-4459
internet: <adme3dz@rvcux1.rvc.cc.il.us>

Vallejo, CA

Jack Tamargo
West Coast Representative
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
internet address: jtamargo@bmpcoe.org

York, PA

Sherrie Snyder
Manager, Information Services
MANTEC, Inc.
P. O. Box 5046
York, PA 17405
(717) 843-5054
fax: (717) 854-0087
internnet: <snyderss@mantec.org>

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
frglcc@aol.com

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
Plymouth Executive Campus
Bldg 630, Suite 100
630 West Germantown Pike
Plymouth Meeting, PA 19462
(610) 832-8800
FAX: (610) 832-8810
http://www.engriupui.edu/empf/

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing productivity and part

reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

Manufacturing Science and Advanced Materials Processing Institute

The Manufacturing Science and Advanced Materials Processing Institute (MS&MPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&MPI:
Mr. Dennis Herbert
Manufacturing Science and Advanced Materials Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 11804-0030
(814) 865-8205
FAX: (814) 863-0673
dbh5@psu.edu

- **National Center for Advanced Drivetrain Technologies**
  The NCADT supports DOD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

  Point of Contact for NCADT:
  Dr. Suren Rao
  National Center for Advanced Drivetrain Technologies
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-3537
  FAX: (814) 863-1183
  http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

  The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

Point of Contact for SEMTC:
Surface Engineering Manufacturing Technology Center
Dr. Maurice F. Amateau
SEMTC/Surface Engineering Center
P.O. Box 30
State College, PA 16804-0030
(814) 863-4214
FAX: (814) 863-0006
http://www/arl.psu.edu/divisions/arl_org.html

- **Laser Applications Research Center**

The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

Point of Contact for LaserARC:
Mr. Paul Denney
Laser Center
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-2934
FAX: (814) 863-1183
http://www/arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

Appendix G

Completed Surveys

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
(Rockwell Defense Electronics
Collins Avionics and
Communications Division)
Cedar Rapids, IA
October 1987 and March 1995

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
(Lockheed Martin Tactical Aircraft Systems)
Fort Worth, TX
May 1988 and August 1995

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
(McDonnell Douglas Aerospace (St. Louis))
St. Louis, MO
January 1989 and May 1995

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C^3 Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Department of Energy-
Oak Ridge Facilities
Operated by Martin Marietta Energy Systems, Inc.
Oak Ridge, TN
March 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993

McDonnell Douglas Aerospace
Huntington Beach, CA
April 1993

Crane Division
Naval Surface Warfare Center
Crane, IN and Louisville, KY
May 1993

R. J. Reynolds Tobacco Company
Winston-Salem, NC
July 1993

Hamilton Standard
Electronic Manufacturing Facility
Farmington, CT
October 1993

Harris Semiconductor
Melbourne, FL
January 1994

Naval Undersea Warfare Center
Division Keyport
Keyport, WA
May 1994

Kaiser Electronics
San Jose, CA
July 1994

Stafford County Public Schools
Stafford County, VA
July 1994

Lockheed Martin
Electronics & Missiles
Orlando, FL
April 1995

Wainwright Industries
St. Peters, MO
June 1995

Philadelphia Naval Shipyard
Philadelphia, PA
June 1993

Crystal Gateway Marriott Hotel
Arlington, VA
August 1993

Alpha Industries, Inc
Methuen, MA
November 1993

United Defense, L.P.
Ground Systems Division
San Jose, CA
March 1994

Mason & Hanger
Silas Mason Co., Inc.
Middletown, IA
July 1994

U.S. Army
Combat Systems Test Activity
Aberdeen, MD
August 1994

Sandia National Laboratories
Albuquerque, NM
January 1995

Dayton Parts, Inc.
Harrisburg, PA
June 1995

Lockheed Martin
Government Electronics Systems
Moorestown, NJ
October 1995